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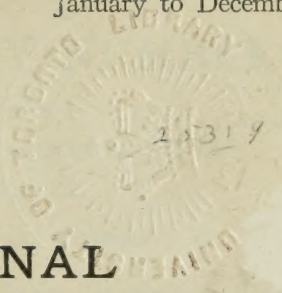




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Vol. XV.

January to December, 1910



**JOURNAL**  
OF THE  
**WESTERN SOCIETY**  
OF  
**ENGINEERS**

PAPERS, DISCUSSIONS, ABSTRACTS, PROCEEDINGS

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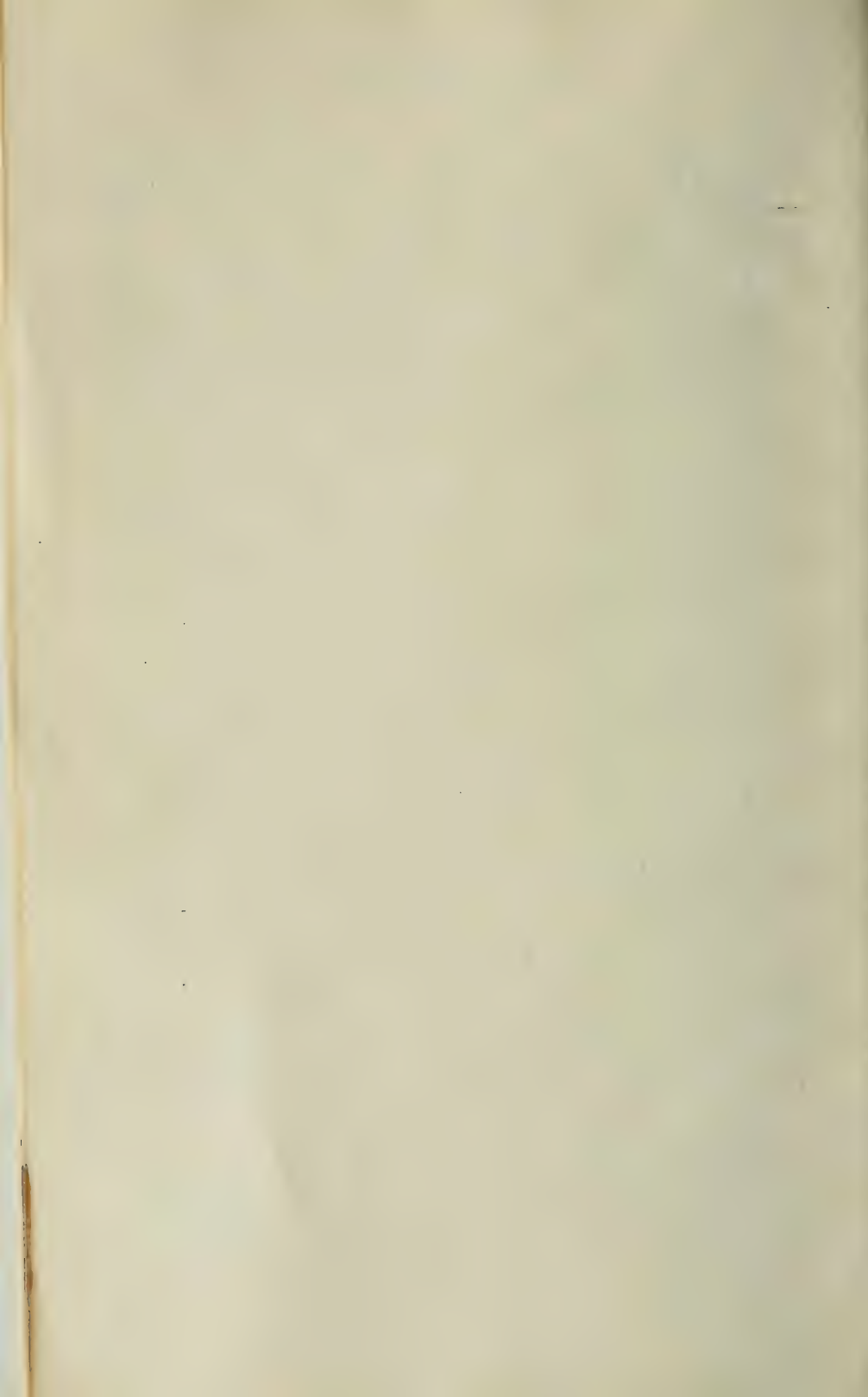
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*John W. Alford*

President W. S. E.—1910.

# Journal of the Western Society of Engineers

VOL. XV

FEBRUARY, 1910

No. 1

## THE ANNUAL MEETING OF THE SOCIETY.

January 12, 1910.

Address of Mr. Andrews Allen, Retiring President W. S. E.

*Gentlemen:* This is the fortieth annual meeting of the Western Society of Engineers, and the management is glad to report that our Society has shared the general revival of prosperity during the past year. Our statistics of membership are as follows:

Number in all grades January 1, 1909.....	993
New members elected (also 14 transfers).....	160
	<hr/>
	1,153
Losses by resignation.....	26
Losses by death.....	7
Dropped from all causes .....	34
Failed to qualify .....	1
	<hr/>
	68
Total membership January 1, 1910.....	1,085
Net increase, 92.	

Number of applications for membership and transfer received during 1909.	202
Number on hand from 1908.....	12
	<hr/>
	214
Number passed .....	174

Applications remaining to be acted on..... 40  
The largest previous record, so far as I know, was 146 applications received during one year.

Our Financial Statement for 1909 has been complicated by the fact that we were forced to collect part of our 1909 dues during 1908, in order to help meet the cost of our new quarters. But after adjusting these differences, the following is our operating balance sheet:

### RECEIPTS.

1909 dues paid in 1909.....	\$8,475.72
1909 dues paid in 1908.....	1,091.15
Entrance fees .....	1,393.00
Advertising .....	2,620.90
Miscellaneous income .....	1,609.04
	<hr/>
	\$15,189.81

### EXPENSES.

Journal account .....	\$4,848.54
Library account .....	550.83

House expense account .....	4,623.29	
Miscellaneous expenses .....	3,989.11	
		14,061.77
Net gain for 1909 .....		\$ 1,128.04

We have held 35 meetings during the year of 1909 as follows:

Regular meetings .....	10, with average attendance, 87
Extra meetings .....	11, with average attendance, 88
Electrical Section meetings held jointly with	
Chicago Section A. I. E. E. ....	9, with average attendance, 162
Bridge and Structural Section meetings.....	2, with average attendance, 82
Ladies nights, social meeting.....	3, with average attendance, 133
Total .....	35, with average attendance, 110

The average attendance at our regular meetings has increased from 60 during 1908 to 87.5 during 1909, and at our extra meetings from 55 during 1908 to 88.0 during 1909. The Electrical Section has had a season of unexampled prosperity, owing partially to the fact that they have been holding joint meetings with the local section of the American Institute of Electrical Engineers, which has greatly increased the attendance at their meetings.

Following the success of the Electrical Section, a Bridge and Structural Section has been organized with a membership of about 190. Several meetings have been held and projected, and a great deal of interest has been developed. I hope that other Sections will be organized. Ours is a great Society covering all branches of engineering, and it seems to me that the only way to unify it is by allowing a certain amount of diversity. We should aim, however, to make our Section meetings as informal as possible and to encourage our younger members to become active in them. If this is done, I believe that they will be a source of great strength to us.

The character and interest of our papers is evidenced by the attendance at our meetings, and I believe we have fully maintained the high standard of past years.

The Chanute medals for papers presented during the year 1908 have been awarded to the following:

Horace E. Horton, for his paper in Civil Engineering, on "The Wrought Compressive Member for Bridge Trusses."

A. N. Talbot, for his paper in Mechanical Engineering, on "Tests of Cast Iron and Reinforced Concrete Culvert Pipe."

Morgan Brooks, for his paper in Electrical Engineering, on "Alternators in Parallel."

In addition to these matters I want to call attention to the efficient work of our committees.

First.—For the establishing of a mural standard of length. The committee has secured a suitable location in the new City Hall and has arranged for the purchase and installation of the standard, which will be donated to the City by the Western Society of Engineers and witnessed by a suitable bronze tablet.

Second.—Our Committee on affiliation of other engineering societies has recommended that our by-laws be amended so as to provide for the formation of branches of non-resident members wherever such action is considered advisable. I trust that this recommendation will be acted upon favorably so that the needs of our non-resident members may be better provided for. There is no reason why we should not have strong and active branches in many cities throughout the West.

Third.—Our Committee for the establishment of a school of mining at the University of Illinois has rendered valuable services in that direction, and the school has been established by act of the Legislature.

Fourth.—Our Committee for revision and codification of the state building laws has co-operated with other important interests toward the appointment of a state commission for this purpose. A bill was passed by the Legislature last spring, but was vetoed by the Governor on account of some technical defects. A new bill has been introduced in the present session, and we are working for its passage, with every hope of success.

Fifth.—No report would be complete without mentioning the Committee for Increase of Membership which was appointed from our younger members, and has done splendid work as indicated by the results.

Several other committees will be mentioned later in my remarks, but I want to add right here that it has been a great privilege to the President to have had such hearty and efficient co-operation from all the officers and committees during the past year. I want to thank them all, and to say before you now that any measure of success that may have come to us during the past year is due largely to their labors.

Now as to the future. And it is one of the privileges of those about to die (officially I mean) to unburden themselves of the great thoughts they are saving up for others to put into practice. The future is a most fascinating subject. We sometimes think we can get along pretty well without our past, but what would we do without the future. It is the abode of ideals, in which time, space, and difficulties are annihilated and where things are seen under the smile of the "God of things as they ought to be." All true philosophy is optimistic, and the ideals that we create for ourselves are by no means dead or imaginary things. They are real and perhaps in a way more real than the things we can see around us; for these pass and change without ever stopping to ask our leave, while our ideals will live with us as long as we give them home and comfort, and it does not make very much difference whether they ever come true or not so long as we strive for them.

So with our Society, it is necessary to have our ideals. The various problems that come up will be settled as they come, and will be settled right if we are right at heart. That is if our ideals are

right, and if they really live in us as they should. I believe that our Society has a great destiny; the Engineer is taking a larger and larger place in the social organization, and our Society should encourage and reflect his progress. It seems to me that there are three principal objects or ideals for which our Society stands.

First.—Towards ourselves as an educational organization. There is no such thing as stagnation. Every one is either growing or retrograding. Continued progress for each one of us depends upon the open mind, active within itself but constantly reaching out for knowledge and sensitive to each ray of light from whatever source it comes. The more we learn the more we realize that the Universe itself contains all knowledge, and that true education consists in placing ourselves in harmony with it, laying aside our own selfishness, receiving truth from every source and sharing it with all seekers for knowledge. The more we know, the larger becomes the unknown, and the smaller we ourselves in proportion to it. The only thing that saves our self-esteem at all is our God-like power of Becoming; and we realize it when we see where we are now compared with the humble beginnings of mankind.

There is no sadder sight in the world than the man that "knows it all," and has tried to keep it all for himself. He has built up all the windows of his house so that no light can enter, and, like poor Ulrich Brendel, has locked up all the knowledge of the world into a little casket, and when he opens it, behold, there is nothing there. The young man just out of college sometimes imagines that he has "got his education," and that all he has to do is to favor the world with a little of his knowledge. The self educated engineer is often better off, in a way, as he doesn't quite know when to stop. There is no line where education ends and work begins. The college man sometimes loses lots of time and gets lots of hard knocks before he learns this lesson, although he has quite an advantage if he regards his education simply as a "flying start" in the race of life, and not anything very great in itself. Again, this is an age of specialization, and an engineer soon gets into a rut if he allows himself to be entirely absorbed by his specialty. As a result, his brain may be over-developed in one direction, but his very nature will be dwarfed.

Our Society fills the need for the *continuous education* and for the *building of men*. It should afford opportunity for the specialist to study his own problems, and it should bring him into contact with other specialists in the same line so that they may each learn from the other and go further than either alone. It should give each engineer opportunity for studying engineering in the broad field in which the work of the world goes on. We must learn to make our discussions appreciative and constructive, or where it is necessary to criticise, to do so without harshness or personality, and to receive criticism in the same spirit, knowing that the progress of the art is the only thing that counts after all, and that we grow and

improve with the progress of our Art. We must never presume to settle engineering questions, or to adopt standards. Such things have their place in executive work, but not here.

The second object for which we ought to stand, reaches towards those outside of the profession, but connected with engineering work. Our membership must have a definite and positive meaning. We should refuse our fellowship to no one connected with engineering work, but our duty also compels us to classify our membership so that the world will take our badge as a diploma of attainment. In order to get this recognition there must be no counterfeits issued. Our different grades of membership must be established, the world must know what they are and our applicants must be classified rigidly on the lines adopted. It is needless for me to say that the present classification of our membership does not meet our needs except in the most general way. Our highest rank requires only five years of engineering work, of which two may be in college, only two years responsible charge of work, and only twenty-five years of age, and there is no grade between Junior and Active. The grade of Associate is really not an engineering grade at all. I trust that the next administration will be able to revise our membership requirements so that, on the one hand, we shall have room in our ranks for every one doing real engineering work, and, on the other hand, all grades of our membership will mean something, and our highest grade will be equal to the highest grade of any of the national societies.

Another matter of vital importance, as affecting our relation to the public, is the legal status, or rather lack of status, of our profession. It is hard to believe that under our present law, no engineer, whatever his attainments and ability, can get a permit for a building in the State of Illinois. Yet such is the case. The architects have been good politicians and have managed to create an artificial monopoly of the building business, thus forcing the engineers to go to them for their commissions. No wonder some consulting engineers in structural work have a hard time making a living when they are prevented from selling their services directly to the owner, and when every architect who feels like it can be his own engineer, or hire a draftsman at \$60 per month to do his, so called, engineering work. We engineers ought to follow the example set us by the architects. We owe it to the public, and to ourselves, to see that this condition is done away with, and a definite legal status given to our profession. Some progress in this direction has already been made by one of our committees. I believe that it is necessary for our Society to take a decided stand on this question, and I trust that the new administration will be able to carry on this movement, and earn the gratitude of the profession and of the whole community by its accomplishment.

And this leads me to the third object of our Society; that of its duty to the community. And in this matter engineers are pro-

verbially lacking. I can easily understand why politics are distasteful to an engineer. We deal with the forces and laws of nature, absolute, true, and impartial. We live in a realm of truth. No wonder that the game of politics does not appeal to us, but, nevertheless, I think we shall have to swallow some of our distaste for such things. In every community the burden should fall on those best able to bear them. Our political organization certainly needs improvement. This cannot be done by laws, except as they reflect the will of the community. Progress must begin with the individual. We engineers are peculiarly fitted by temperament and training to take a lead in public affairs. We usually have some object in life besides getting rich, and the community needs just such men. To take up the problems of the city, state, and nation, to study them intelligently, and to help others to study them. To work for the improvement of conditions. To serve the city or state gladly and faithfully when called upon to do so, and to put duty to the community and pride of work well done, above everything in the world.

It is not necessary, except in special cases, for the Society, as a whole, to take a stand on public questions. I can easily conceive of cases in which we should do so, but usually I think such actions would do more harm than good. We should keep in touch with all public questions related to engineering, through committees which should frequently report to the Society. In this way we shall be familiar with the various problems and will know how to act patriotically and wisely as individuals. During the past year we have discussed the Chicago smoke problem and the harbor situation and a committee of our membership is keeping in touch with the harbor question. It is expected to make a report very shortly so that we may get at the facts from an impartial and authoritative source. I believe that this active interest in our municipal problems ought to be continued, and that some of our meetings ought each year to be devoted to such things.

We need have no doubt for the future if we can keep such ideals firmly before us. Only let us remember that it is the work that counts, not the personal glory or the rewards. It is a privilege and a great education to take part in the "work of the world," and mankind is the end as well as the beginning. We are here as a part of a great evolutionary plan and have our work to do. I do not believe that what we think or do is lost any more than energy is destroyed when coal is burned. One of the greatest English poets has said:

"\* \* \* All that *is* at all, lasts ever, past recall.  
 Earth changes, but thyself and God stand sure,  
 What entered into thee, that was, is and shall be  
 Time's wheel turns back or stops, Potter and Clay endure.  
 He fixed thee 'mid this dance of plastic circumstance,  
 This present, thou forsooth would'st fain arrest,

Materials just meant to give thy Soul its bent,  
Try thee, and turn thee forth sufficiently impressed."

So with all that we do, nothing is lost. It fixes its imprint on us and on the world, and we may find, after all, that the poet's vision contains a greater truth than the wisdom of all science. It gives us a purpose in life and an unwavering faithfulness to it. It inspires every act, every thought, with the idea that we are living in Eternity and for Eternity, for nothing is lost. All that we do well for our Society, for our community, or for ourselves, is worth while and will bear its fruits. This is the higher meaning of work. Perhaps not a matter for cold analysis but none the less an idea that we can live by and die by.

I cannot close better than by repeating a few lines written by a famous American who believed in the gospel of work and the spirit of democracy.

"A worship new I sing  
You Captains, Voyagers, Explorers—Yours  
You Engineers—You Architects, Machinists—Yours  
You, not for trade or transportation only;  
But in God's name and for thy sake, Oh Soul."

I now have a pleasant duty to perform; to pass the leadership of this Society into the hands of your choice for 1910, and to present to you a man who needs no introduction, President John W. Alvord.

#### ADDRESS OF PRESIDENT-ELECT.

*Mr. John W. Alvord:* Gentlemen of the Western Society of Engineers—It is a time-honored and ancient custom of our Society to hold this annual gastronomic function, review the achievements that we have accomplished, talk perhaps a little about what we are going to do in the future; but incidentally to trot out a brand new president, poke him in the ribs, examine his teeth, and see him go through his paces so as to satisfy ourselves that he can trot a suitable heat for the year to come.

Now, this is a very pleasant and delightful function indeed for everybody but the trotter, and it is calculated to fill a man with a considerable degree of humility when he looks back upon the long array of brilliant pacers and trotters that have preceded him in the years gone by. It dawns upon him that it is just possible that the Society has not kept up its record; that a spur or whip may be needed, possibly a little dope forced down an unwilling throat in order that he may successfully pass under the wire in some sort of proper shape so as to befit the coming occasion at the end of the year.

I have looked over the list of the presidents of this Society with considerable diffidence. There are distinguished gentlemen who

have built great power plants, tremendous bridges, world-renowned canals, and even dreamed dreams of deep waterways to the sea for the benefit of our posterity, and I have turned with humble mind to my own past record and tried to find something that looked like a monument. Only one thing occurs to me which possibly you may excuse me for mentioning here: There was a time when an admiring board in a small town where I was doing sewage work voted to carve my name on a stone inserted in the wall of the town septic tank. In my fondest dreams, gentlemen, I have at least yearned to send my name down to posterity in somewhat more savory fashion than this, and I want to thank this Society from the bottom of my heart for giving me some other opportunity to perpetuate myself.

The office of president of such a society as this seems sometimes to the man in the street as sort of a reward, or perhaps a prize, and possibly it is; but it is something more than this: it is a call to be the servant of the Society to look to the broader interests, the larger vision that will benefit it. It is essentially an office of service and I can say no more at this time than that it is my sincere desire that so far as I am concerned that service shall be the thing which lies next to my heart in the coming year. Now, in a broader way the profession of engineering is sometimes looked upon perhaps by some of our members as a means of getting a livelihood and possibly even of making some money. But I think as years come to us and we grow to see the real meaning of life we come to feel more deeply that the profession to which we have given our life is after all the opportunity to be the servants and to do service to our fellow men; to make human society happier, better, more comfortable, and more thoroughly imbued with the spirit of love, and to bring out its higher and finer qualities rather than to allow it to degenerate into the bare struggle for existence.

It has been my lot particularly to be engaged in the service of municipalities and to become to some extent their adviser in public sanitation, and I have come into contact more largely with those engineers whose business it is to solve the problems of the municipality than any other part of the profession. I have a very large sympathy for these men, for they labor under very unusual and embarrassing conditions. Their tenure of office is often short. They are theoretically far removed from their client, the general public. If they do creditable work it is very seldom realized or appreciated. If by mischance they make any slip or mistake the judgment on them is often harsh and severe. No other section of the profession, to my mind, struggles against conditions which evolve pessimism to so great a degree as do the conditions which surround the engineers serving the municipality, and especially those in a salaried position.

It has for some time been my thought that this society can do no better work than to upbuild and strengthen this part of our profession. It is rather discouraging to see the small proportion of municipal engineers that are members of the Society. There is

something about their struggle with the conditions that they have to meet that breeds hopelessness and a sensitive exclusiveness, and they lack to a large degree that broader optimistic view which they would get in a society of this sort. I think perhaps I am safe in saying that fully four-fifths of the engineers in the service of the city of Chicago are not members of this Western Society of Engineers. Here is an expensive society plant, a valuable library, beautiful assembly rooms, opportunities for printing proceedings, everything that is necessary for them to have their conferences, to discuss their special problems, and to develop that bond of sympathy with their fellow-associates, and it is all seemingly neglected. It has been in my mind, as a hopeful possibility for this coming year, that we might organize a municipal or hydraulic and sanitary section (I do not know what name is quite appropriate for it), which would do this work. Such a section would increase the temptation to these men who need us and whom we need, to enter our Society, to discuss all problems that come before them with us and with themselves, and to acquire all of the advantages and the benefits that we can give them.

But it is not for me to talk too much about the future. We have before us a feast of good things, and I want to clear the way for them. We are all interested in the patriots who have gone out and fought for their country amid great toil and hardship. We like to read and hear about them and know of all their vicissitudes and their struggles; but of late years it has dawned on us all that there is another kind of patriotism, the patriots of peace who devote their energies to their country, to matters of public welfare, and who, though quiet and silent, much unknown, are yet doing great good in their way, in their time and in their place and generation for their fellow men. We are to listen tonight, gentlemen, to some of these patriots of peace. The first one of them who is to speak to us, quite unlike some of the early patriots who shouldered a flint-lock and went out to fight for decreased taxation, went up to our taxing office and asked that the valuation of his particular corporation might be justly increased. This patriot is well known to you and there are many other grateful things which the city of Chicago owes to his efforts and his thoughts and his care. I take pleasure in introducing to you the speaker of the evening, Mr. B. E. Sunny, President of the Chicago Telephone Company.

#### THE ENGINEERING OF CHICAGO.

*Mr. B. E. Sunny, President Chicago Telephone Company:* If the riches of a city were measured by the civic interest and pride of its citizens, Chicago would certainly be the richest city in the world—for nowhere is there a larger number of earnest and unselfish men making plans for any city, and at no time in its history have there been so many proposals for vast municipal undertakings as now.

While our present capable and progressive city administration

has taken the initiative in many important matters, it has able allies in planning for Chicago's present and future greatness and glory in the clubs, associations and many local improvement organizations, as well as individuals—all of whom have given generously of their time, thought and energy in solving the problems of the municipality.

At this meeting of engineers my purpose is to submit for your consideration a statement of the principal suggestions for permanent city improvements, very largely as engineering problems, although the questions of enabling legislation and finance are necessarily brought in and must be dealt with.

The list of suggested permanent improvements is as follows:

New Sewer System.

High Pressure Water System.

Steam Railway Terminals.

Plans of Local Board of Improvements for Replacing Pavements in the Business District.

Deep Water Way.

Harbors.

Subways.

And last, and greatest of them all, the "Chicago Plan" of the Commercial Club.

Taking up the items in the above order, the situation appears to be as follows:

#### NEW SEWER SYSTEM.

The present sewer system in the business part of the city was installed in the early sixties, and, of course, has long since reached the limit of its capacity. A sewer system three times larger than the present one is urgently required.

A report of the Bureau of Engineering, made in March, 1906, probably during dry weather, as no rain is mentioned, showed many of the 12-inch sewers running full, and many evidences in the man-holes that the water rose to a height of from 3 to 4 feet above the invert. The large sewers were mostly flowing about one-half full, with a strong, clear current. Under these circumstances, a rainfall of any magnitude will cause the water to back up in basements, as it actually does in many regular places, particularly along Clark and Dearborn streets, where the buildings are large and crowded, and the sewers are small. For the most part the sewers in the business district are 1 foot in diameter and they are from 10 to 14 feet below the surface. This depth gives sufficient drainage for ordinary shallow basements, but of course is inadequate for the deeper basements.

Connections from buildings to sewers are in many cases of 9 inches, and it is a common occurrence for the 12-inch main sewer to run full under a head for a longer or shorter period, as the house sewers empty their full capacity.

It is a common sight in Chicago, after a rainfall, to observe repairmen of the telephone and electric companies at work around

manholes which are filled with water, and it will also be recalled that when the street railways were operated by cable the channels through which the cables ran were frequently filled to the surface of the street with water from manholes for several hours after a rain-storm.

#### HIGH PRESSURE WATER SYSTEM.

The movement to establish a high pressure water system in Chicago began in 1903, with the passage of an ordinance creating a commission to draw plans for the work. The subject was dropped until it was again taken up in 1908 by the Council Committee on Local Transportation.

High pressure water systems have been installed in New York, Providence, Hartford, San Francisco and in several other cities of less importance. The idea is to supply a volume of water under sufficient pressure so as to be in immediate readiness to fight any fire without the aid of fire engines.

It has been thought that a system of the kind should be in the center of every large city, but experience seems to indicate that the greater danger of a conflagration is from the outside, where the buildings are of inferior type, for the reason that many of the buildings in the center of the city are of fireproof construction, and the number is increasing every year.

The latest installation of the high pressure system in New York is in the tenement district on the East Side, where if a conflagration started it would be a serious menace not only to lives in that populous district, but to the lives and property in the business district which connects with it on the west and south.

As fireproof buildings in the business district of Chicago increase, taking the place of the buildings of inflammable construction, the need for a high pressure system may be found to be immediately around the business center on the North, West and South Sides, as a protection against a conflagration having its origin considerably outside of the business district, as was the case in 1871.

Aside from the added safety to the city and its people from a properly installed high pressure water system, the financial saving in a lower insurance rate is very important.

A high pressure water system in the loop district will cost about \$600,000.00, and the saving in insurance premiums would be more than \$150,000.00 a year, or 25 per cent on the cost.

Such a system covering the territory from Chicago avenue on the north to Twelfth street on the south, and to Halsted street on the west will cost \$3,800,000.00.

There are no figures available at the moment covering the insurance carried in this territory, but the saving in insurance from the installation of the high pressure water system in Philadelphia is said to be 25 per cent, in Manhattan 15 per cent, in Brooklyn 20 per cent and at Coney Island 25 per cent.

Aside from the protection to life and property, a high pressure

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system seems to be justified in Chicago from the standpoint of a good investment by the city and the citizens.

#### STEAM RAILWAY TERMINALS.

The plan as originally published by Mr. Frederic A. Delano was to reduce the number of railway stations from six to two, although since then the Chicago & Northwestern Railway has settled on a station of its own, and the minimum number would now be three.

The plan included one new station, or a group of stations, on Twelfth street, between State street and the river, and another station on the west side of the river on Canal or Clinton streets, between Madison and Twelfth; also that Twelfth street be made 150 to 200 feet wide, and that the level be that of the present viaduct.

With his long practical experience as an operator and officer of steam railways, Mr. Delano carefully worked out all of the necessary details of handling the traffic, baggage and freight of the many trunk lines involved. His arguments in favor of a consolidation of railway terminals are strong, and in many respects conclusive.

In urging his plan he says, among other things: "An improvement in the present situation is very much needed—perhaps more needed than any of us realize. The extent to which people are actually driven away from Chicago by the aversion they feel to the city, growing largely out of what they see as they enter and leave it, means a very serious loss. Some one has well said that the gateway of a large city is its railroad terminal, and from this gate the great majority gain their impressions. What has already been done in European capitals and in this country in some of our larger cities hardly needs to be referred to. By co-operation of the railroad companies, the municipality and the public-spirited citizens, the railway terminals in Boston, which for a long time were anything but a credit to that city, have been brought up to a high and creditable standard. Immense sums are at the present time being spent for this purpose in New York City and Washington, and a number of other large cities have comprehensive plans in view. Chicago, the leader of them all as a railway terminus, cannot afford to remain behind."

Mr. Delano's plan also proposes the straightening of the Chicago river between Twelfth street and Sixteenth street. At this point the river now bends abruptly towards the lake and then back again to the west. Straightening the channel will put a considerable amount of property now on the west side on the east side of the river, and will make the river more readily navigable.

#### PLANS OF BOARD OF LOCAL IMPROVEMENTS FOR REPLACING PAVEMENTS IN THE BUSINESS DISTRICT.

The Board of Local Improvements estimates that next year twenty-four blocks in the loop district will be paved with creosoted blocks at a cost of about \$150,000. The President of the Board

says that the plan was to pave as many streets in the loop district as possible with creosoted block, but the work has been kept back because of possible subway construction. Relief from the present defective and noisy pavements must be had, however, and the Board is going ahead with the work on the assumption that nothing will be done on the subways for three or four years.

The following are the streets to be paved:

Randolph street, from Clark to La Salle.

La Salle street, from Randolph to Jackson boulevard.

Clark street, from Lake street to Madison.

Washington street, from Clark street to La Salle.

Monroe street, from Clark to La Salle.

Randolph street, from State to Michigan avenue.

Wabash avenue, from Randolph to Washington.

Monroe street, from Dearborn to Michigan avenue.

Adams street, from State to Market.

Quincy street, from State to Dearborn.

#### DEEP WATERWAY.

All are familiar with the projected Deep Waterway from the Lakes to the Gulf, and an issue of \$20,000,000 of bonds towards this enterprise has been authorized by a popular vote in Illinois.

A pamphlet published in St. Louis, says: "The main artery of this waterway system is the 14-foot channel, ultimately 22 feet, that is to be built from Chicago to New Orleans, 1611 miles, so that sea-going vessels may steam from the Lakes to the Gulf of Mexico without breaking cargo. The Chicago Sanitary District has built 40 miles of this waterway, to Joliet, and Illinois has voted \$20,000,000 of the \$31,000,000 needed to complete the work to St. Louis.

"By the investment of \$400,000,000 in improving the Mississippi river and its tributaries, \$180,000,000 a year can be saved in freight charges. In other words, this is an enterprise that offers a return of 36% per annum on the capital required to develop the amazing possibilities of the vast and fertile heart of the American Continent, that is capable of supporting 400,000,000 people—more than four times the population of the United States."

A picture of the Chicago river at its mouth is shown in this pamphlet, underneath which is the legend:

"Chicago Harbor. 1611 miles to New Orleans. Greatest Railroad Center in the World. Converging Point of Trade to Great Lakes; 20,000,000 Tons of Water-borne Commerce Annually; \$1,115,000,000 Output of Factories; Biggest Livestock Center, 17,000,000 Head; Biggest Grain Market, 225,000,000 Bu.; Largest Packing House Trade, 3,400,000, Lbs."

While we are not required to take these figures seriously, it is nevertheless the fact that the people of Illinois have authorized an expenditure of \$20,000,000 for the Deep Water Way, and

the only entrance now provided is the Chicago river. What it is proposed to do with the Chicago river is pointed out in the report of the Chicago Harbor Commission, appointed by Mayor Busse, and of which John M. Ewen was Chairman.

#### HARBORS.

In the summary of recommendations of the Chicago Harbor Commission, appointed by Mayor Busse, is found the following: "Chicago River (Main and South Branch), Widening the main river to 250 feet; completing the work of widening the South Branch to a minimum of 200 feet; replacing center pier and narrow span bridges on the main river and South Branch with bridges having a clear span of 200 feet; cutting out the elbow at Rush street on the south side of the river; cutting off projecting elbow south of the Chicago Northwestern Railway bridge at the northeast angle of the main forks, and making a turning basis at the present forks of the river; straightening the river from Twelfth to Sixteenth street; illuminating the river by electricity for navigation at night; diminishing the current, especially in that portion of the river between Lake street and Twenty-first street; the establishment of a number of public docks on the river, situated at localities convenient for the distribution of freight.

"It is also recommended that the Lake Front between Randolph street, on the South Side, and Chicago avenue, on the North Side, be reserved for future harbor developments."

In a separate report by John M. Ewen, Chairman of the Chicago Harbor Commission, on the Chicago Dock Problem, the following statement appears:

"The problem of proper dock development in this community presents many difficulties, complexities and uncertainties, and is closely related to other unsolved problems, especially that of proper rearrangement of railroad terminals.

"An era of reconstruction and of tremendous improvement is believed to be directly ahead for Chicago. Nothing should be done that can not be made to fit into whatever larger plan may be worked out."

If the Chicago river is to be the mouth of the Deep Water Way which is to handle enough traffic to have justified an investment of more than \$500,000,000, the plans of the Harbor Commission for improving and widening the river are none too large. It is a practical question, however, whether the Chicago river, running through the heart of the second city in the United States, can be used for any such purpose.

The alternative is to make an entrance to the Deep Waterway through the proposed channel from the Calumet to the Drainage Canal, which, of course, would mean that what little there is left of Chicago's marine traffic would disappear prac-

tically entirely, and we will then have reached a point where fixed bridges can be discussed.

#### SUBWAYS.

The first plan for a subway is by Mr. Arnold, and it contemplates a system of high-level subways for the North and South Side lines, and low-level subways for the West Side lines; the low-level subways to be built for double track on Adams and Madison streets, and the single track on Van Buren, Washington, Franklin streets and Michigan boulevard; the high-level subways to be built for double track in State street and Dearborn street, and single track in Clark street and Michigan boulevard.

The tunnels under the river would be at Van Buren, Adams and Washington streets, connecting with the West Side, and at La Salle, Dearborn and Wabash, connecting with the North Side.

I understand that these subways are for surface lines only, and do not include elevated roads.

Mr. Arnold points out the objections to low-level subways, which are as follows:

*First.*—Relatively higher cost than high-level subways.

*Second.*—The passengers in the low-level subways would be about 40 feet below the surface of the street, thus necessitating the use of elevators between low-level and high-level subways at station points—a distance of about 20 feet.

*Third.*—The engineering difficulties and risks that would be encountered in its construction.

*Fourth.*—The fact that it would interfere, and to a large extent destroy existing and contemplated low-level improvements.

Mr. Arnold's last recommendation, made in January, 1906, is also for surface roads only, and covers a low-level subway from the Van Buren street tunnel, single track in Van Buren street to Michigan boulevard; thence to Washington street; through the Washington street tunnel, with a single-track connection between the two tunnels on Franklin street; a double-track high-level subway on State street from about Fourteenth street to Monroe, with a single track north to Randolph, west to Clark, and also a single track west on Monroe to Clark, and on Clark to Randolph, where the two single tracks would become part of a low-level subway running west to La Salle and into and through La Salle street tunnel to the North Side.

The suggested initial subway routes by the Committee on Local Transportation, are for surface and elevated roads, and are as follows:

Four-track subway in Wabash avenue from Twenty-second street to the Chicago river, dividing at that point into two two-track subways, crossing the river and taking different routes, and terminating at Chicago avenue and North Franklin street.

A three-track subway in Randolph street, and also in Washington street, and two-track subways in Adams and Jackson streets, making the loop in a four-track subway in State street and terminating on the West Side at Halsted street, between Lake and Randolph, and at Halsted street between Van Buren and Congress.

I am referring very briefly to the several suggestions, giving merely the barest outline of what they include.

The planning of the various suggested undertakings represents a great deal of hard work, and they are entitled to more liberal treatment in the matter of detailed explanation, but the time at our disposal, and the use that we can make of them on this occasion will not permit of it.

#### CHICAGO PLAN.

It seems a great injustice to take up the Chicago Plan and not devote hours to it, which it is fully entitled to, but for the reasons just stated, we will touch upon it only to the extent that it has a bearing on permanent municipal improvements.

The Chicago Plan is now in charge of the Chicago Plan Commission, made up of 355 citizens, appointed by Mayor Busse, and of which Charles H. Wacker is Chairman, and my understanding is that it is a part of the program of this committee to present it to the people of Chicago, through illustrated lectures and otherwise, so that in a few months this great undertaking—one of the most remarkable that has ever been suggested for any city—will be fully understood.

The Chicago Plan, among other things, proposes widening and beautifying many existing thoroughfares, and the creation of a number of new thoroughfares, mostly streets running diagonally.

The scheme, to a considerable extent, consists in circuits, the innermost of which includes Michigan avenue, Twelfth street, Canal street, Washington street, while the outermost circuit, starting at the lake, near Indiana, goes all around the city and ends near the Wisconsin line.

Among the thoroughfares that it is suggested should be widened are Graceland avenue, Diversey boulevard, North avenue, Indiana avenue, Chicago avenue, Washington street; while Congress street will be opened through, and very much widened, and make a connecting link between Michigan boulevard and the West Side, starting out from the front of the proposed Field Museum, and running to the proposed civic center at Halsted street. The new Congress street will be 200 or 250 feet wide the entire distance.

It is suggested that Twelfth street should become a great viaduct, beginning at grade at Michigan avenue and extending elevated over to Canal, and it should not be less than 180 feet in width.

Also, Sixteenth street and Twenty-second street should be widened, and it is thought it would be wise to widen all section-line streets running east and west, and the half-section streets; also La Salle street and La Salle avenue.

South Park avenue, which is the extension of Grand boulevard, should be carried over the Illinois Central right of way from Twenty-second street to Grant Park, over which it should pass to that railroad's north freight yards; thence over the yards and the main branch of the river, and on until it connects with the Lincoln Park Lake Shore Drive on the North Side. This would form a continuous outer boulevard, connecting Lincoln Park and the South Park System.

The plan urges vast improvements in the Chicago river, and in addition suggests that boulevards should extend from the mouth of the river along to the north and south branches and on both sides at least as far as North avenue on the north, and Halsted street on the south.

Regarding the much-desired connecting link between the South Side and the North Side at Michigan avenue, the report recommends that all of the buildings on the east side of Michigan avenue from Randolph street to the river be removed, which would permit the broadening of Michigan avenue, so as to take in Beaubien court, making a thoroughfare 246 feet wide.

The crossing of the river will be made on a double-deck bridge, the upper for boulevard traffic and the lower for heavy traffic.

These several suggested great public improvements have been presented one by one at different times during the past three or four years, and each in its turn has held the attention of the public for a time. It is not until we gather them all together, however, and consider them as a whole, that we fully realize their true significance, which is that the time has arrived, in fact it arrived some time ago, and we only partially recognized it, when our municipal structure of public works must be reconstructed, rearranged and greatly enlarged.

It is not pretended that any one of the several problems enumerated has been worked out definitely or finally.

Approximate figures of cost are shown in some cases only. As the several items now stand they represent suggestions of public works, many of which ought to be secured. It does not follow that they will all be adopted, or if they are, or a portion of them, that their present form will be adhered to.

There are two fundamental requisites involved in the situation:

*First.*—A comprehensive and complete engineering plan of all municipal works for the longest period practicable.

*Second.*—Legislation; and money.

With regard to a comprehensive engineering plan: The several suggested permanent improvements, for the most part,

stand by themselves, and do not always take into account their influence or bearing on each other. In some respects they conflict. They need to be taken in hand, with all other public improvements that are in contemplation, and analyzed and modified as may seem best, and finally worked into one broad scheme which shall include everything that we are likely to require for many years to come.

This does not mean that the whole work of making these improvements shall be undertaken at one time, but it is the idea that whatever is done shall be in accordance with a general plan, to be adopted as soon as possible, so that the work of successive years will always fit in with what has already been done.

The question that arises is: is the city equipped in an engineering way to properly analyze, co-relate and harmonize all of these suggestions, and to finally fix upon one comprehensive plan which shall embody them all, or such number of them as are found good.

The answer to this is that the city is without the necessary engineering organization for undertaking so large a task.

On April 27, 1908, Mayor Busse sent a communication to the City Council, pointing out that the time had arrived when the question of underground transportation in Chicago must be seriously taken up. This was concurred in by the Council and the Committee on Local Transportation was directed to make an extensive investigation as to the condition of the streets with respect to water and sewer systems, gas mains, electric conduits, etc., and to make a recommendation on the subject of subways.

This committee, under the direction of Ald. Milton J. Foreman, with the assistance of engineers employed specially for the purpose, made the first and only complete engineering study of the city that has ever been made. The data collected and printed in the three volumes which constitute the report of the committee, will be for years of the greatest value and assistance.

On the completion of the work the services of the several engineers were dispensed with, so that the City Engineering Department is much as it was before the report was made.

In all large corporations there are complete engineering plans covering the entire property, and these plans are laid out for a growth of anywhere from five to twenty-five years.

In the Steel Corporation, provision has been made for the supply of raw material for fifty years. The new plant at Gary is planned for growth for twenty-five years.

The steam railways have their plans worked out for at least twenty years ahead, and when the time comes for the additional track, although it may not be for ten years, the way is clear of stations, buildings and other obstructions, so that the work can be done at the smallest cost.

In the telephone practice, new exchanges are located with reference to the expected telephone center of the particular district, and the building is planned for the maximum fill, although at the outset the building and the equipment provided may be but 25 per cent of the maximum. The additions that are then made from time to time fall into place in orderly fashion, and at the minimum of expense and time.

The same is true of all properly organized corporations, and it is not necessary to multiply instances.

Owing to the outgrown and inadequate organization of the city there are few if any plans, especially in connection with the water and sewer departments. The engineering problems which arise from day to day are settled as best they can, and without any special reference to the future. Having no broad plan to work to there is nothing else that can be done.

With all of these splendidly thought out suggestions of useful and vitally necessary improvements, plus the routine requirements of a large and growing city, I strongly urge that the city be supplied with a board of high-class engineers, to whom shall be referred all data on the property now owned by the city, and all of the suggestions that have been made with respect to improvements. An engineering board, made up of specialists in the several lines, such as subways, water, sewerage, railways, harbors, etc., could in a brief time make a definite and no doubt satisfactory recommendation with reference to the all important matter of subways and could also, in a year or eighteen months, submit a complete plan for Chicago which would be a standard to work to for many years to come.

As has already been said, the "Chicago Plan" and the other important suggestions, are general rather than specific. They are submitted merely as suggestions. They must be brought together and made to harmonize if any good is to be had from them, and this work can be done only by experienced engineers.

To illustrate, the "Chicago Plan" does not include subways, and some of the subway plans do not harmonize with the "Chicago Plan." As a matter of fact, in one of the subway plans, the western terminus of a subway, at which point both elevated and surface lines leave the subway and go on the elevated structure, or on the surface, is where the "Chicago Plan" has located the civic center.

Again, the Board of Local Improvements, through the vigorous and continuous complaints of citizens, has been driven into a campaign of permanent pavements in the loop district, and is putting down some of the best pavements that we have ever had, including a concrete base of from 8 inches to 12 inches in thickness.

Madison street has just been completed, at an expense of about \$6,000.00 a block, while one of the subway plans locates a subway in Madison street, which, of course, would result in the destruction of this pavement. Not only that, but the expense of the subway is increased by having to deal with this mass of concrete in the way,

which would be very much more expensive to remove than an old pavement without concrete base.

The Board of Local Improvements, under a continuing pressure to improve streets, is therefore pushing its work, regardless entirely of subways, sewers, high pressure water system, and all else.

There are three distinct suggestions concerning the connecting link between the North and South Sides at Michigan avenue, a surface crossing at the river, an elevated and surface crossing, and a subway under the river.

It is in the matter of subways, however, that we find our most pressing and difficult problem, and also the widest differences of opinion. In their recommendations of location for, and types of subways, the Committee on Local Transportation and Mr. Arnold are far apart, and there are still other plans by outside engineers that are of value and they differ from both.

As we have been delayed for one reason or another in the adoption of any subway plan, there has been time to make a general survey of the situation and look at Chicago not only in the loop district, but all over. The city spreads out for miles north, south and west, and to arrange for the conduct of its passenger traffic is a more difficult task than in New York, where the travel is north and south.

Because of the more favorable conditions in New York one four-track subway through the middle of the narrow island can carry 860,000 passengers in one day, and the elevated roads an additional 860,000, a total of 1,720,000, while all of our elevated roads put together carry in the same time but 450,000. The New York traffic by subway and elevated is four times that of our elevated roads.

The figures for the surface lines are not at the moment available, but they probably show the same results—that the north and south lines in New York are more effective than are the north, south and west lines in Chicago.

In Chicago we have a greater mileage of track and a larger number of cars of all kinds in proportion to the traffic than in New York. This means that we are operating less efficiently.

For years the business district has been regarded as the terminus of all transportation lines, and some of the subway plans so far submitted perpetuate this idea in planning loops in this district. If the New York transportation problem is simple and it is made so by the fact that it is north and south only, is it not possible to rearrange our transportation lines, especially in connection with the proposed subways, so that they, too, will be north and south only? It appears that we can come so near doing so that I think the plan is well worth considering, and it is this:

A four-track subway in State street, from about Twelfth street to about Indiana street on the North Side, for surface lines.

A three-track subway in Dearborn street, from about Twelfth

street to Chicago avenue, and in Chicago avenue to North Franklin street for elevated service.

A four-track subway in Clark street, from about Twelfth street to Indiana, or Ohio street on North Side, for surface lines.

In addition to through routing between the South and North Sides, re-route the Twelfth street line and all lines south of Twelfth street on the West Side, so that they will come into either the State street or Clark street subways on the south and re-route the Chicago avenue line and all lines from the points north of Chicago avenue so they will come into either of the above subways on the north.

By this arrangement, we will have made the surface transportation of the city all north and south through the business district, except that portion of the West Side lying between Taylor street and Indiana street. This will leave out of the subways the lines on Van Buren, Adams, Madison and Randolph streets, which would continue to operate on the surface and loop on Wabash avenue.

This plan would permit of the removal of all surface track on the north and south streets in the loop district except Wabash avenue and on all of the east and west streets except Randolph, Madison, Adams and Van Buren.

It would dispose of about seven-tenths of the surface lines in the loop district, do away with all surface crossings which are the principal cause of congestion, reduce the traffic on the Union loop by more than one-half, and would involve the building of only about five and one-half miles of high level subways, practically without curves, and with no crossings.

As Chicago grows and more subways are required, we have left for additional subways Michigan boulevard, Wabash avenue, La Salle street, Fifth avenue and Franklin street. It is inconceivable that Chicago will ever produce more traffic in and to the business district than can be cared for by the north and south arteries in that district. Nor is it probable that we shall ever build low level subways, not only because of the objections that Mr. Arnold has pointed out, but because low level subways have been tried in London and have proven a failure. Forty millions of dollars have already been lost on the low level underground railways in London, and it will be some years before the complete story can be told. There is nothing to indicate that it will ever be a cheerful story.

Confessedly there is a difference between the American and the Englishman, but the difference is not so great that if you sent 5,000,000 Americans to London they would put the auto-busses out of business and use the underground exclusively. In our love of daylight, sunshine and good air, we are not behind our English brothers, and tunnels and subways are not attractive unless we are in a hurry and are willing to sacrifice something to gain time. I am therefore rather confident that we shall never have low level subways, with elevators at each station in Chicago, but that we shall

limit ourselves to as small a mileage as is practicable of high level subways.

Curiously enough, in my judgment at least, it is not any part of the subway work done in any city during the past ten years that seems to be the best, but it is the subway under Park avenue, New York, from Thirty-third to Forty-second streets, that is pre-eminent for speed, safety, convenience and comfort. This subway was built thirty years or more ago, and in addition to being immediately under the surface there are many openings in the top which admit light and air. State street is wide enough to permit of similar treatment, but our other thoroughfares are not.

The subway that Chicago will build will be for all time, and it must be right in location, in design and construction. It would be an inexcusable blunder if at the very outset we failed to secure the best engineering talent for the purpose of solving the problem.

With regard to legislation and finances, the situation is as follows:

For more than thirty years the city of Chicago has had no means with which to do anything more than, in a more or less imperfect way, to keep the municipal machine in operation. It has been continuously in default in furnishing its share of street improvements, a proper water supply, sewers, bridges, school houses and other necessary adjuncts to a large and growing city.

The bonded indebtedness of Chicago thirty years ago was about \$20,000,000, which was the limit allowed by the State Constitution, and it is now about \$26,000,000. In the meantime out of the \$6,000,000 secured from the sale of bonds and from direct taxes and licenses, the city, after paying operating expenses, has added more than \$50,000,000 in value in land, school buildings, water tunnels and water supply, electric lighting system, Police and Fire Department buildings, etc., etc. The area of the city has increased from thirty-six square miles in 1880 to 190 square miles at this time, and the demands of the annexed territory which Chicago took upon herself, with no means of supporting it, have been even more urgent than those from the original territory.

Handicapped as Chicago has been for want of capital all of these years, we should be grateful to the successive city administrations for their economy and frugality; otherwise our condition would not be even as good as it is.

There are still many citizens who have the impression that all of the taxes collected in Chicago on real and personal property go into the City Treasury.

As a matter of fact, out of \$4.47 collected on the South Side the city receives \$1.35, or 30 per cent, and out of \$4.91 collected on the West Side, the city receives \$1.35, or 27 per cent. The balance, 70 to 73 per cent, is divided among the state, county, sanitary district, schools, Lincoln Park, South Park and West Park.

The state is rich and has no debt. The county, sanitary dis-

strict and the parks can and do sell bonds when they need additional funds. They have always been liberally provided for. The city alone, to us the most important of these municipalities, has been tied down until recently by a constitutional limit on bond issues, and, while we have been free from this restriction for about six years through the adoption of the amendment to the constitution in 1903, we have not been able to secure the advantage of the removal of the restrictions because of our failure to get the necessary legislation from either the General Assembly or the people of Chicago.

As this whole question must necessarily come up again, and the sooner the better, let me refresh your recollection as to the facts.

The Constitution of the State, adopted in 1871, limited the bonded indebtedness of municipalities to 5 per cent of the assessed value of the property, and the assessed value was fixed at one-fifth of the full value.

With \$2,000,000,000 of property in Chicago at full value, the assessed value at one-fifth is \$400,000,000. The amount of bonds at 5 per cent which could be issued on \$400,000,000 was \$20,000,000.

As I have explained, this limit was reached thirty years ago, and the taxable value of property as returned by the Assessor increased scarcely at all from year to year, and there was therefore no authority to put out additional bonds.

In 1903 we succeeded in securing an amendment to the Constitution so that, among other things, bonds could be put out on the basis of 5 per cent of the full value instead of the assessed value of real and personal property. Therefore, on a valuation of \$2,000,000,000, a bond issue to the extent of 5 per cent would give us \$100,000,000. The conditions were, however, that Chicago must first consolidate with one or more municipalities operating within the city, and

That the outstanding bonds of the city and of the parks and that portion of the county and of the sanitary district lying within the city limit, must be included as a part of the 5 per cent.

It was therefore necessary, in order to take advantage of the amendment with reference to increasing the bond issue to consolidate with the parks. A consolidation between the city and county and the sanitary district was found to be impracticable, for the reason that the territory of the county and of the sanitary district is very much larger than that of the city.

After the constitutional amendment was secured, the Charter Convention was organized, by the appointment of seventy-four delegates, named respectively by the Governor, the General Assembly, the Mayor, the Common Council, the County, the sanitary district, the parks, etc., and it submitted a new charter, which not only included the authority to consolidate the city and the parks, but also to put out additional bonds and about fifteen additional subjects. Many of the subjects got into the Charter by a bare majority, so that

when the work of the Charter Convention was completed there were few of the members who felt at all satisfied with the work.

The General Assembly amended the Charter in many respects, and in doing so increased the dissatisfaction so that when the charter was voted on in Chicago a few months later, it was defeated by a vote of 121,000 to 60,000.

It was afterwards decided that among the mistakes that had been made was the one of putting so many subjects in one bill, and requiring the voter to vote yes or no on the whole proposition.

The second attempt of the Charter Convention to get necessary legislation, resulted in a drafting of eleven separate laws, which in this new form included substantially the things covered in the first Charter, but the last session of the Legislature failed to pass any of them.

In the meantime, foreseeing the difficulties of getting Charter legislation, Mayor Busse and his associates originated the so-called "Mayor's Bonding Bill," which was a state-wide measure, and after a vigorous and energetic campaign, led by Comptroller Walter N. Wilson, the bills were passed. The effect of those bills is to authorize in Chicago \$16,000,000 of additional bonds, with the condition that no bonds can be legally issued until the proposed expenditure is ratified by a referendum to the people.

It is under this Act, that the City Administration has included in the budget just completed, \$10,000,000 for permanent improvements, as follows:

Water Plant Improvements.....	\$1,197,500
Bridges . . . . .	2,738,173
New Fire Department Stations.....	753,900
New Police Department Buildings.....	1,065,500
For Completing New City Hall.....	3,500,000
Miscellaneous . . . . .	579,000
Library Branches . . . . .	250,000

It will be seen, however, that of the \$16,000,000 it is proposed to spend \$10,000,000 just as soon as it can be done after the ratification by the vote of the people. It will also be recognized that there is not an item in those enumerated that it not urgently necessary. The vote ratifying the new bonds ought to be practically unanimous.

After this expenditure is made, there will be \$6,000,000 to be expended, and then Chicago will be again up to the limit, and will be without funds to make further permanent improvements, except out of current taxes.

Among the eleven bills submitted to the last Legislature, none of which passed, was the so-called Consolidation Bill. It covered the consolidation of the City and Parks as required by the Constitution, and the right to the City to put out additional bonds. If the bill

had passed the General Assembly, Chicago's authority to put out bonds would have been increased to about \$50,000,000.

A broad generalization of the financial condition of the City is that it needs its present income from taxes and licenses (and more, too) for ordinary operating expenses, and can spare no part of it for permanent improvements; that with the \$6,000,000 of bonding authority under the Mayor's bonding bills unused, the sum accumulated from the 55 per cent of the net profits of the traction lines, and the contributions which the traction companies are required, under their ordinances, to make to the building of subways, there is not more than \$15,000,000 in sight, and omitting subways, upon which we can at least make a start, there is no financial provision for any of the other important permanent improvements which are required.

It would be idle therefore to discuss them were it not for our confidence that the people of Chicago will soon wake up and do their duty.

Chicago, commercially, is the wonder of the world. Chicago, municipally, is a laggard. If we had stopped commercial development in Chicago at the time when the municipality exhausted its ability to raise capital to pay for permanent improvements to keep step with the commercial improvements, we would be back where we were in 1880, with a population of about 500,000. Chicago commercially is thirty years ahead of Chicago municipally.

In this matter of furnishing the necessary funds to the City, we must not be influenced either by the stories of extravagance and waste in New York on public improvements through the neglect or complacency of the citizens, or by the alleged misbehavior in the public expenditures by petty officials in Chicago. New York, Chicago and other large cities have almost always been open to charges of the kind, and still in 20 years there has been a vast improvement in the type and character of municipal officers, and there is now a higher efficiency and integrity than heretofore.

In any event, to refuse to provide money to pay for permanent improvements because of the fear that some of it will be stolen, is to confess that our method of government is a failure, and that we are incapable of self-government. This I am sure we are not ready to do.

While we have an abundance of civic pride, we seem to be lacking in courage in the matter of supplying funds to the municipality, and confidence that they will be properly expended.

We shall not do our beloved City justice by equipping her to hold the position among the greatest cities of the world, which is her manifest destiny, until we get together and add to our civic pride, *courage*, to supply the money and *confidence* that it will be well spent.

In conclusion, and to summarize, my recommendation is that the so-called Consolidation Bill should be again urged upon the General

Assembly and the people, in the interest of a better and more efficient municipal organization in Chicago, especially for the purpose of financing needed permanent improvements, and that the City be encouraged in the necessary expenditures for a Board of Engineers, to make up a comprehensive and complete engineering plan for Chicago's future public works.

*President Alvord:* Our committee of arrangements for this meeting invited some members of the St. Louis Engineers' Club to address us, among them one whom you all know. Mr. M. L. Holman has sent his regards in a letter so significant that I am sure you will all give it your close attention and hearty approval.

Jan. 8, 1910.

Mr. Andrews Allen,  
President Western Society of Engineers,  
Chicago, Illinois.

Dear Mr. Allen:—

In reply to your invitation to the annual meeting and dinner of the Western Society of Engineers, I regret that my engagements for next week will not permit me to be present.

As President of the Engineers Club of St. Louis, I extend the congratulations of the club on your fortieth anniversary and best wishes for your future prosperity.

As an individual Engineer I take the liberty of suggesting that the Western Society of Engineers consider the question of taking the initiative in founding an American Institute of Engineers on lines broad enough to include both the Engineers who build a country and the Engineers who will have to operate it.

Our parent National Society permitted an unnecessary multiplication of so-called "American" Societies which are practically National in name only and which can not, under present plans of operation, expect a long life or best serve the interests of the Engineers of the future, or for that matter the graduate of today who intends to devote his life to the Engineering Profession.

Yours very truly,

(Signed) M. L. HOLMAN.

*President Alvord:* I am somewhat of a pessimist on some forms of our municipal government, forms which are now probably soon to pass away under the newer municipal movement in our American politics. But I am an optimist on the magnificent body of men who are devotedly and conscientiously struggling to do useful things for the public and to make municipal governments better so as to accomplish what it is intended to accomplish. We have with us another of those patriots of peace, and I think you can perhaps hardly realize the extent and multiplicities of duties that devolve upon the chairman of the Finance Committee of the City of Chicago. My personal observation has been that he is a man hard pressed with a great many important functions, and if the newspapers are to be

believed, he is capable of being some evenings in three places at once. I take pleasure, therefore, in introducing to you the Alderman from the Seventh Ward and chairman of the Finance Committee of the City of Chicago, Mr. Bernard W. Snow.

*Mr. Bernard W. Snow:* Mr. Chairman and gentlemen of the Western Society of Engineers: Ex-President Allen in the course of his remarks indicated that engineers do not care to get very close to the practical politician. I do not know that this is particularly a new idea; I think I have heard it before, but I may say that the average politician is a man who undertakes to accomplish results. If he is to be successful at all, he must get results and I am well aware that in some directions, at least, engineers of this Society, such as are represented here tonight, are not the ones that we come in closest contact with.

There are engineers and engineers. Alderman Foreman and myself have been doing a little job of engineering ourselves today. We have done most of it civilly; we have engineered the passage of an appropriation bill, the budget of the City of Chicago for the next year, carrying a total of about sixty million dollars. A pretty good feat of engineering for one day.

And another thing which Mr. Allen's remarks suggest, is that we sometimes have other dealings with another class of engineers, and in our desire to get results we do not come to the Western Society of Engineers to find them. If, for example, I have a little primary deal that I want to have engineered I go to a perfectly competent engineer; I will take my friend Buck Higgins, who does not belong to your Society, but he gets results.

Now, I am not clear as to just what engineering discussion you will expect from an ordinary layman. I have had a little dealing one time and another with some of your membership. I remember a couple of years ago when my very good friend Hibbard, here on my right, spent about nine months explaining to me, day after day, that a layman, such as I was, was not expected to know anything about the engineering difficulties that beset the Chicago Telephone Company, and that I should accept what he had to say about it.

On another occasion it was explained to me that a politician was not expected to know very much about engineering when my friend Cowdery was talking to the council committees, for that beatific and beneficent institution, the People's Gas Company, which he is the head of at the present time; he told us we did not know anything about these engineering problems and he would work them all out for us if we would kindly give him his own way. So, with more or less frequency, some of us in public life are brought in touch with different classes of engineers,—engineers and engineers.

There is one thing in Mr. Sunny's very able statement tonight that impressed me particularly though possibly not in exactly the manner in which it was intended. He refers to the fact that among the large engineering problems which Chicago will be called upon to

deal with in the near future is one of the matter of rebuilding, readjusting, and rearranging a sewer system in the downtown district. There is no question but what that is a problem which must be faced and faced soon. But, my friends, the suggestion of that problem brings to my mind this: We are somewhat prone to believe that in our own day and generation we do things better and that we are bigger-minded and broader-minded, and that we see farther and plan better than did men in the older days. But let me call your attention to the fact that the sewer system in the downtown district in Chicago, built as it was practically all prior to the fire in 1871, so that with the loss of records at that time the date of a large part of its completion is unknown. The newest part is more than forty years old, and think what forty years means in the development of such a community as we have in Chicago. Yet in spite of this the men who laid out and planned that system built along lines and with a keener knowledge of the future of Chicago than a good many of our engineers are building today.

Take the case of the sewer on Madison street. It is a sewer that was built more than forty years ago, and at a time when sub-surface drainage for city sewage was not a problem that had been worked out as it is now and was not accepted as entirely the best method of sewage disposal. But the men who planned that sewer forty years ago, built it upon plans that were generous enough so that it answers the requirements today except when there is some abnormal storm with storm waters to carry off. A sewer that was laid at a time when a portion of the territory it went through was market gardens, and yet which forty years afterwards has had added to it at one time the sewage flowing from a great building like the La Salle Hotel, turning into it more than the total sewage that was turned in at the time it was built; in spite of this it is measurably adequate for the present day. Now I wonder if forty or fifty years from now, those who succeed us on the stage of affairs in Chicago can say of the men who built and planned in our days, that we had an equally full knowledge and an equally abiding faith in the growth of the city of Chicago?

There are great engineering problems to be worked out here. There are great problems other than engineering. We in Chicago are undoubtedly working out the greatest problems of municipal government of any municipality upon the face of the earth. We have conditions of population, conditions of race, with ideas and customs gathered from the world over, that we have been fusing into one composite here in American democracy. But laying aside all of those problems and considering tonight merely those suggested by Mr. Sunny it seems to me that the most important of them all is to get within ourselves an abiding faith and a confidence in what Chicago is to be. There are men here tonight who may reasonably hope to be active and influential in Chicago forty years from now and who, if they are, will dwell in the greatest center of human ac-

tivity that the world has ever known—a Chicago that will hold from fifteen million to eighteen or twenty million of people, and in making your plans today they must be made, for municipal problems at least, with that development in mind. Planning for anything less will leave us open to the criticism, in a very few years, that we lacked faith in our town and in our generation.

One of the problems which Mr. Sunny dwelt upon and which I am going to touch upon also, not for the purpose of discussing it in any detail, but merely to illustrate this point which I have in mind—that of necessity of building for the future and building for the manifest destiny of Chicago. It is the problem of local transportation which is the greatest problem in any city. The growth and development of Chicago, as with every town, must depend upon the rapidity and the flexibility of the means of local intercommunication. The radius of a man's action from his own physical powers is necessarily limited, and without a system of local transportation we could never have anything more than a series of detached villages. The transportation problem in Chicago is the greatest problem, and I believe that we should consider it as one single proposition. We have not done so in the past. We have considered street railway transportation as an independent, separate problem. We have built our elevated railroads on the same principle, and we are now making the same mistake in planning for our subways.

The three forms of transportation are necessarily correlated, and must be so dealt with if we are to secure the highest efficiency in transportation. The surface lines must of necessity be slow in speed with their radius comparatively limited. Their proper function is the building up of neighborhood centers, the short haul; and in order to secure a perfect system there should be a combination of the local system as exemplified by the surface road, and the through-routing, long distance, high-speed travel, either by elevated or by subways. In building our elevated roads we have built to increase the congestion in a certain section of the city rather than to furnish free and fair transportation. When four great double-track trunk lines converge upon a single double track loop circling within a small area, it soon becomes a physical impossibility to operate satisfactorily either in the center of the town or on the outlying feeders of the elevated. What we should understand is that the various systems of transportation should co-operate; the surface line gathering up and carrying either to a loop or to an elevated railway, those who desire to make long distance journeys, and carrying them, not to the downtown district but through the downtown district, to be again redistributed at the end of their run by the surface line.

If we are to consider the subway as an engineering problem and regard it simply as a means for doing away with the present congestion in traffic, we are only touching one-half of the problem; and twenty-five years from now, those active here will say as we do now of those in charge of affairs when the loop

structure was permitted, that they failed to grasp the fundamental principles of the transportation problem.

Mr. Sunny has also indicated something of what Chicago must come to in the matter of the so-called Chicago Plan. That again in its larger sense is simply an evidence that in the past we failed to appreciate what we were doing. We must submit to the economic waste which results from tearing out what we have done in order that we may build over again upon a more generous and a more comprehensive plan. We must come to it, and if we had had, as Mr. Sunny suggests, an engineering department of municipal affairs big enough and broad enough, and with sufficient authority to make out plans, not for the immediate present nor for tomorrow, but for the future years to come, we would not now face the problem of spending millions, yes hundreds of millions of dollars to undo the very things which we have been spending our money to do in the last fifty years. So that I can most heartily agree with the suggestion that the municipal government of Chicago could make no better investment than to come into closer relations with the engineering profession and to secure the services as an important part of government, of such board of engineering experts as has been suggested.

Now, as I said in the beginning, I do not propose to carry coals to Newcastle, I do not like work well enough for that. I do not know as there is anything I can say from the technical side of these engineering problems, but to the layman I believe that even you men, keen as you are and clear sighted as you must be to practice your profession successfully, are yet failing to grasp the significance of what you are doing and what we are doing in its relation to what the Chicago of the future is to be.

*President Alvord:* I cannot refrain from reminding the society that the well deserved compliments of the last speaker on the down town sewer district of Chicago are due to the labors of one of our long-time faithful members, and an honored past president of this society, Mr. E. S. Chesbrough.

We are disappointed that Mr. Felton, who was to be our next speaker can not be with us tonight, but we have in his place a gentleman who has given careful attention to matters of transportation and electrification of railways. I take great pleasure in introducing to you the Chief Engineer of the Chicago Great Western Railroad Company, Mr. L. C. Fritch.

*Mr. L. C. Fritch:* Mr. Chairman, Members of the Western Society of Engineers and Gentlemen: I think perhaps you all will be disappointed that Mr. Felton was not here, when I get through. I did not know I was to speak until I came to the meeting tonight, so that I will have to apologize if my remarks are short and to the point.

Mr. Sunny has so thoroughly covered the matter of engineering in Chicago that there remains very little to be said. However, there is one branch to which he referred but briefly, upon which I will make a few remarks, and that is the relation of the railways to Chicago in an engineering sense. Mr. Snow has covered thoroughly the ground of local transportation, but there is another form of transportation in which the City of Chicago is interested, perhaps, not to the extent that it is in local transportation, but to the commercial interests, in a larger degree, and that is the handling of freight traffic. The railroads of Chicago aggregate about 2,000 to 2,200 miles of track within the city limits, which in itself makes quite a respectable system. The railroads, like everything else in Chicago, were planned for the immediate present. The future was not considered. So, in my mind, the revision of the freight terminals of Chicago is almost as great a problem and as great a necessity as any other problem we have.

The present method of handling freight traffic of Chicago is practically no different from what it was 25 or 30 years ago. It is done in the same crude manner on unscientific lines and with waste of money and time. About four years ago, a comprehensive plan was evolved which proposed handling all freight traffic through a series of yards on the outer belt lines. This system contemplated that no through traffic should pass into the congested part of Chicago. It was estimated at the time that if such a system was put into effect, the average delay to cars passing through Chicago would be reduced from about 72 to about 36 hours. That in itself would be quite a saving. On the other hand it would reduce the cost of operation a sufficient amount to pay the interest on the cost of establishing this terminal system. The reason why the plan has not been carried out is because some of the lines having superior facilities were unwilling to give them up. But the time is coming when the railroads of Chicago must, perforce, be compelled to go into some such system.

The question of handling freight traffic is of the greatest importance to the commercial interests and if properly done, will save untold thousands of dollars each year. One reason why a large amount of traffic is kept out of Chicago is because the cost of handling it between freighthouses and warehouses is so excessive by reason of our congested streets that a large amount of traffic which otherwise would come to Chicago, now goes from the point of manufacture direct to the point of distribution, and Chicago in this way not only loses in its commerce but its transportation. Because traffic is diverted to lines that do not pass through Chicago.

The ideal arrangement in Chicago for freight and passenger terminals would be to, as nearly as possible, make union ter-

minals. In almost all large cities, and especially in St. Louis where, perhaps, the idea is carried out to a greater extent than anywhere else, one large terminal handles practically all of the freight and passenger traffic. While that scheme might not apply to Chicago, yet one or two such terminals or perhaps three would simplify the situation here to such an extent that other improvements could be easily made.

The question of electrification is a delicate one for any railroad man in Chicago to talk upon today. I do not think it is a question we ought to be afraid of. It is one of the economic changes of the times; it is going to come and I believe that the sooner we face it and work out the problem the better off we will be. If we do not face it and do not work it out, we will be met by compulsory legislation that will force it upon us before we are ready for it. While electrification is considered impracticable today in a large freight terminal, it is made so by reason of conditions now existing. If the railroads of Chicago would adopt Mr. Delano's idea or some similar one in the consolidation of passenger terminals, the electrification of passenger traffic would be very much simplified. If the freight traffic of Chicago were handled on the outskirts of the city, where it would be unnecessary to electrify the large yards, and the local traffic in Chicago were handled through a minimum of belt lines, it would again simplify the electrification of freight terminals. But before all this can be done there must be a comprehensive plan worked out, and I have advocated the idea of Mr. Sunny for a commission not necessarily all composed of engineers, but some good practical business men as well, for the purpose of working out some comprehensive plan of handling our railroad terminal problems. We have an illustration in Chicago of what co-operation between corporations and municipalities can do in track elevation; when first broached in Chicago it was thought it would bankrupt all of the railroads, yet there is not a railroad company today that would be willing to go back to the surface. It would be impossible to maintain the schedule speeds within the city limits of Chicago if it were not for track elevation. While track elevation and electrification are not parallel problems, yet I am one of those who believe that the time will come when a system of electrification will be worked out that will be so economical that the railroads can afford to adopt it. That time, however, is not yet here. One great objection to electrification today outside of the question of practicability is its cost; but the engineering profession is so prolific of talent that I believe the time is coming, and soon, when the cost of electrification will be reduced so that it can be installed economically, and more economically than steam.

I think that Chicago, by reason of its geographical location, its great commercial interests, and its large population, should be

the home of engineering in America. I believe that the University of Chicago should have a school of engineering that would be the best school of its kind in this country, because right here in this center and radiating therefrom, the talent from such a school could be most usefully employed.

*President Alvord:* You are all aware of the tremendous importance of the problem which has been and is now confronting this city in the matter of local transportation. Much of the control of this situation centers in our present committee of the council on local transportation. We are fortunate in having with us tonight not only a patriot of peace but a patriot of war. I take pleasure in introducing to you the Chairman of the Committee on Local Transportation, Col. Milton J. Foreman.

*Col. Milton J. Foreman:* Mr. Chairman and Gentlemen—Unlike my friend Sunny and my railroad friend, I am not an engineer, and unlike my friend Snow I am not a politician. Whatever offices I have held have been by the demand of the people, not by the chicanery of any engineer, and I do not recognize any engineer who is not fit to be a member of this Society or who is not qualified to be—with some trifling exceptions.

Now, Mr. Chairman and gentlemen, I am somewhat of an optimist. I can not conceive of a condition whereby Chicago could have been born just right and completed at once; and I would not want to live here if it had been. I know of but one place where perfection and perfect peace exists, and that is in the cemetery. That is the last place I want to go to.

That Chicago is rough on the edges, a little unkempt, and that it has outgrown its clothes, is to its great credit. It has grown too fast for its people to keep up its good clothes. They have been too busy getting clothes for themselves. Chicago is the Cinderella of the State of Illinois; that is what is the matter with it. Within the county of Cook there are a lot of favorite children. Every time a citizen wants to take a kick at one of the municipal children, he selects the city of Chicago. When the Park Boards want some candy in the shape of bonds and taxes, the people say to them: "Why, certainly, my dear child, help yourself." When the Sanitary District wants to double its taxes they say: "Surely. We don't know just exactly what it is for, but for Heaven's sake, fill yourself up." When the City of Chicago says, "We have increased in thirty years from thirty square miles to one hundred and ninety-four square miles and we would like some policemen and a few lamp-posts, and we would like to issue a few bonds," the answer is: "You cannot have them, because we need a park and we need a new boulevard." But Heaven forefend that we should need policemen and garbage cans. We have developed the front-yard theory, the parks, the old New England idea of having one room which is always in order, tidy, and a sepulchre where we can receive our company; damn the back yard. The result is we have dumped our taxes and

our bond issues into the favorite children's laps, and poor old Cinderella has been struggling along the best she could and has not even once had a chance to ride in a pumpkin chaise—not once. As Mr. Sunny pointed out, we had that beautifully gilded chaise once and I was one of the drivers, and they only beat us two to one. They could have done better than that. But the fact remains all the same that unless we consolidate our energies and our money to get Chicago to be a real city, and quit wasting our substance on fancy things and folderols, we will never get a city, no matter how much we resolute or how much we may seek it.

A good city is a well balanced city, and it is not a well balanced city if it has a surplus of boulevards and a heap of unpaved alleys. A city is not a good city when its garbage is not removed often enough, no matter how many small parks or playgrounds it has. Microbes and bugs breed in garbage cans in spite of small parks and in spite of playgrounds; and I defer to no man in my wish that Chicago should have all the small parks and all the playgrounds it can get, but I want it to go hand in hand with cleanliness, police protection and well paved streets. But so long as park districts and other favorite children in silk gowns can have any kind of bonnet and clothes they want, and the poor old city of Chicago gets belted from Dan to Beersheba—wherever that is—whenever it asks for anything that goes into the very life of the people, you are not going to have a well-balanced city, and you won't have until all the taxes that come into Chicago are put into one place and are dispensed according to the actual needs of the city of Chicago in its material welfare; and all the bonds are issued on the same basis, and not to develop one arm so that it reaches eighteen feet out and another one is stunted up to the elbow.

I have been one of Cinderella's family for eleven years, and it doesn't make any difference where I get kicked now because they cannot kick me in a new place. But I want to tell you that so long as I have a voice I am going to protest against the reckless indifference of the people of Chicago to what really goes to make up a city. We appropriated today a sum, a fraction for street cleaning, garbage removal and other necessities, a fraction of what New York City pays, just a fraction; with our huge surplus of streets, with great, growing wards, each with a population of 100,000 and over, we appropriated the munificent sum of fifty or sixty thousand dollars for garbage removal, street cleaning and ash removal, and street repair for twelve months. Yet this is where the people live and where the money ought to be spent, so we are the Cinderella.

Does anybody ever criticize the actions of any public official anywhere except in the city hall? Heaven forefend. Let a city official sneeze and it is good for two leaders in the newspapers. We cry for publicity in corporate affairs. There is only one municipal corporation in the State of Illinois where true publicity is found, and that is in the city hall. There is not an act or an action of a

city official of the City Council that is not known to every man in the morning when he goes down town and reads his paper on the car, or in the afternoon when he goes home and reads his paper. Tell me, is there anything in the municipal corporation that you do not know about? On the other hand, does anybody know anything about the expenses of any other municipal corporation? All the vice has not been concentrated in the city hall, and all the virtue in the favorite family; but Cinderella is the only one you know about and you will find the average of her virtues beats her vices a heap.

Do you know what any Park Board, or any County Board, or the Sanitary District do? They are magnificently administered bodies, every one of them, but I dare say you will find by comparison with them that the administration of affairs in the city hall equals them, and you know it because you follow it, but you do not follow the others.

Now, Chicago is developing, and it is growing in the right direction. If you will look at the transportation systems of a few years ago and the transportation system now it will tell its own story. As Mr. Arnold will bear out, I believe, the only step necessary to be yet taken is the physical consolidation of the two big properties—to link them together so that downtown you will have the finest surface transportation in the world. Not much is necessary even in the elevated. The unenlightened selfishness of the elevated railroads who refused to get together in amity so that there may be a final consolidation, an operating consolidation, is the only thing that stands in the way there. Whether at any time in the history of Chicago you will be able to carry your people on two levels, as Mr. Sunny suggests, I pass no opinion but I have “me doots.” I do not believe you will ever see a time when you can carry all the people in Chicago on any two roads underground. They cannot do it in New York.

Now, as to your city planning, I believe one of the best things ever attempted in the city of Chicago is this idea of planning for a city beautiful. They will make mistakes, there can be no doubt of it. With 194 square miles, with a territory reaching from Hegevisch, the home of Battling Nelson, to Norwood Park, the home of virtue, there is a stretch of territory that no man can predict truthfully how it will be occupied, by what type of citizenship, whether by manufacturers or by residences. Here is the great Calumet district, in which we are just building a great waterworks system, in which two great sewer systems have just been put, which will throw open this great territory. By what will it be occupied? Perhaps by light manufactories, or perhaps something else. The Twenty-seventh Ward, which a few years ago had 25,000 people, now has 120,000 people. Here are old wards emptying out and some of them filling up again. No man can tell. The best they can do is to guess, and the city will have to be altered from time to time, and when you put the means in the hands of the city of Chicago from time to

time to meet conditions as they arise you will have the right kind of a city; and when you treat every citizen of Chicago and every locality of Chicago, no matter whether they live in one locality or another, alike, then you will have a real city.

Let me say something to you about some of the inequalities of Chicago. We are very proud of our boulevard system. The boulevards are maintained by general taxation. Every man pays for it whether he lives on it or not. Because every man pays for that boulevard and because he pays for it by general taxation, only the favorites are permitted to drive on it, so all the funerals and heavy teams go on the streets that are paid for by the man himself. Now that is reverse English justice. A man who pays two or three hundred dollars for paving his street with asphalt is one block from the boulevard, so the people get their groceries and milk and bury their dead over his street because he pays for it and keep off the boulevard because it is kept up by general taxation. This won't do; we should get down to fundamentals. We are just as lively and just as imaginative and just as active as anybody. We have a first-class city; what we want to do is to get our own house in order—our municipal plan, our municipal scheme—and remember that because a thing is called the city government it is not necessarily bound to be bad, nor are men totally unfit to occupy the place of public office just because they have been elected to that place.

The city of Chicago has an ordinance under which passengers are carried from Seventy-ninth and Halsted streets to Howard avenue for 5 cents. Pretty fair work for a Jim Crow town, isn't it? There is not a day but what there is an improvement in the local transportation system. That we have not made more progress with the subway is not to be mourned at. New York thought of it a good many years before she embarked on the business of building subways, and when she did embark in it she made as many mistakes as we have microbes in one of our catch-basins; and they had to take one of our citizens, Mr. Arnold, to New York to help to straighten it out. It is better that we ruin a few pavements and start right, because you cannot rip a subway from under a pavement any more than you can finance the Illinois Tunnel Company.

Now, just one observation in conclusion, to our friends in the Legislature and the people of Chicago. In a club that I was a member of once a good many years ago they discussed the question, "How shall we uplift the masses?" A great many people talked about it very learnedly and very lengthily, and when they got pretty tired a little man got up in the back of the room and said: "Mr. Chairman, may I speak a minute?" He said "Yes." "Well," the man said, "your question is, How shall we uplift the masses? Well, I will tell you: Get off of them and they will uplift themselves." Get off of Chicago and get under it and lift it and it will take care of itself.

*President Alvord:* Gentlemen, while we are on this matter of

transportation, I am sure you will agree with me that we will all want to hear from one who, while a patriot in many ways, is also affectionately remembered by us as the patriot of the treasury of the Western Society of Engineers, Past President Bion J. Arnold.

*Mr. Bion J. Arnold:* 'I certainly had no idea of making a speech so soon after arriving in this city from the East. On getting to my desk this morning I found two invitations to dinner; one of them to this dinner and one of them to the dinner given to Mr. Calhoun tonight, and had I known what I was going to get up against tonight, as the saying is, I think I would have accepted the other invitation. However, being here and hearing the excellent speeches that have been made, I have derived a great deal of benefit from them and am therefore very glad to be present.

I labor under a bit of embarrassment tonight from the fact that I am in an audience of four of my instructors, you might say. First is the representative of the steam railway company with which I first engaged in business, the Chicago Great Western Railroad, some twenty-two years ago. Mr. Fritch is now the Chief Engineer of this road, for which I was at one time Mechanical Engineer before I left to go into the electrical business under Mr. Sunny. He gave me my first job in electricity. I do not know whether he is sorry for it or not, but I am thankful for what he did for me. He turned me over to Mr. Johnson to give me instruction in salesmanship and I think I once sold a two-horsepower dynamo under his direction; and then Colonel Foreman discovered me when he wanted something for the city of Chicago and he has been sorry several times since. He is still my friend, however. But I am talking under the supervision of these gentlemen tonight, and consequently if I disagree with them very much I hope they will forgive me.

I am interested in Mr. Sunny's outline of a traction scheme for the city and in view of the fact that he has been so good a friend of mine for so many years has given this subject such careful consideration recently, and has suggested some ideas which are new, I think his views should have very serious consideration before they are criticised, so I hesitate in attempting to criticise them tonight. As a general proposition, however, I have thought for some time since analyzing the transportation in this city which began some eight years ago, that we shall need not only the surfaces of the streets in the downtown district but also the subway space under those streets, and possibly the elevated space above the streets, in order to handle the traffic that this city will eventually produce. I do not wish to absolutely commit myself to this position. If there is any other scheme which can be proposed which will take the elevated railways off of the streets I would like to see it done. If we can work out a scheme which will place the north and south cars under the surfaces of these streets, leaving the surfaces of the streets free for the West Side cars as Mr. Sunny proposes, that would be a splendid solution of the problem. I would like to see it done, but I

am afraid when you come to analyze it you will find that the cars would be so thick in these streets he proposes to use as subways we would be unable to get the traffic through on the tracks he proposes. However, my mind is entirely open and I shall be very glad to go into and analyze it more carefully before coming to a conclusion, if I am ever called upon to do so.

In that connection I would like you gentlemen as engineers and business men of the city to bear in mind that the subway plan proposed by me in 1902 in my report to the city, was the result of one or two or at most a few men's ideas. The double-decked plan which was recommended was my own idea, however, and as the entire report was the result of about four months' work, the subway part of it was a very small element, the other elements entering into it being very much more comprehensive; consequently the subway question had to be given very hasty consideration, and the solution therein proposed was simply for a downtown terminal subway, and not a subway which could be called one sufficient for the entire city, but it was so planned that it could be added to so as to take in the outlying districts. Since that report was published my ideas have changed somewhat and I would now add to that system certain branches running north, south and west on certain streets which would make the plan then proposed the nucleus of a comprehensive system. As to whether a doubledeck system shall be used, remains, of course, for the engineers and business men of the future to decide. Mr. Sunny did point out the disadvantages to the system which I named. He failed, however, to mention the advantages which the system has, and, while not attempting to get into an argument over it tonight, as I do not wish to, I still believe that the scheme has many advantages and they are all set forth in this report of mine. Probably when the subject comes up for final discussion and decision those advantages will be discussed and brought out, together with the disadvantages Mr. Sunny has pointed out.

Regarding the suggestions of Alderman Snow and Colonel Foreman, Mr. Sunny, I presume, would coincide with the view that the proper solution of the question is the consolidation of all the elements entering into the transportation question, namely the surface, elevated, and the subway lines. I do not wish to commit all these gentlemen to that policy, but to me this seems to be the best thing to do if we can ever get the situation to that point. It is natural that the surface lines should take care of the short-haul traffic, but it can be readily understood that if the elevated roads are required to give through service from the north to the south part of the city, and vice versa, at the high rate of speed which their trains are capable of running, it would be natural for all passengers to take the elevated lines, and therefore put the burden of the long haul upon the elevated roads and relieve the surface road. Consequently the just way would be to have both roads owned by one company or municipality

so that the loss to one system would be compensated by the advantage to the other.

I think the consolidation of the companies and the introduction of the through route principle on all of the lines would cause a great reduction in the operating expenses, so that possibly the loss would, in a great measure, be offset by the increased traffic. This, however, is something that should be carefully considered before a decision is reached. I am not ready to commit myself to the statement that it would entirely compensate. I do believe in the consolidation, however, and I think the efforts of this body of men and all the other men in the city should be directed toward bringing about this consolidation. I also think that the suggestion made by Mr. Sunny for a board of control, composed of some engineers and some men from the other walks of life, would be a splendid thing for the city. The Board of Supervising Engineers, with which I am concerned, is endeavoring to discharge its duty under the ordinance which created it, but it is handicapped to a certain extent by the perfectly sincere work of other boards of the city, which are not co-ordinated with our board. We endeavor to co-operate as much as we can, but there are certain actions taken by those boards and also by us, which, if we were all in one harmonious body and working jointly, would save us all more or less trouble. Such a board as Mr. Sunny has suggested would eliminate those practical difficulties and get results in all the departments of the city engineering work which cannot at the present time be brought about.

*President Alvord:* We will only detain you a few moments for one more pleasant experience largely in the line of reminiscence. We all wish to hear from one of the very oldest members of the society. I remember well the first meeting of the society I ever attended. It was in the year 1885, I think, under the presidency of Mr. Benezette Williams. We met in a room which housed a furniture exhibit and only one corner of it was lighted. There were present the honorable President, the faithful Secretary and the body of the Society, which consisted of myself and one other gentleman. I cannot help comparing that early meeting with some of the well-filled meetings which we have been having this last year. Fortunately we have with us tonight that faithful Secretary, the first Secretary of the Society, who long and diligently labored through those early years of discouragement and vicissitudes to carry the Society along year after year. I will not pretend to say the number of years, he can tell us that, but we all will be glad indeed in conclusion to hear just a few words from Mr. L. P. Morehouse, the first Secretary of the Western Society of Engineers.

*Mr. L. P. Morehouse:* Mr. President and Gentlemen—I happen to stand here tonight by accident, having had the good fortune to be present at the first annual meeting of this organization, and

being also present at this latest annual meeting, tonight; and so as a historical character I stand before you. That is the only apology which I can make for speaking these few words to you except that your new President has insisted that I should so stand before you and actually convince you that the Society had a beginning.

The discussions and papers tonight have had to do with the future. Fortunately I am not called upon to discuss anything in the future. I am simply, as I say, to call your attention to one thing in the past; the fact that there has been a past to the Society and to all of us, and I simply want to say in connection with what has been said with regard to the work which it has done for the public and what its individual members have accomplished for the benefit of the community, that there is another thing in which this society has been pre-eminently before the public, and that is in the individual lives and character of so many of the eminent gentlemen who have been members of this organization.

You gentlemen build your physical structures, the world sees them, they last for generations; but there is something else that is built up in life besides such monuments; the greatest of achievements is the building up of personal character. I only want to allude to one man, a member of this organization for so many years; I have only time just to call his name, but in this connection, and in view of the fact that he has been referred to here tonight by other speakers, I will mention Mr. E. S. Chesbrough, the second President of this Society and for many years City Engineer of the city of Chicago, who in the early fifties planned the sewer system and the waterworks system of this city, which has been complimented tonight. I only want to say to you that Mr. E. S. Chesbrough was one of the most estimable, the most delightful of men that you could ever have met in your lives. I want further to say that so far as you can learn about Mr. Chesbrough's personal history and character it is a study that will well repay your investigation.

In conclusion I would like to soliloquize to myself by simply saying that I congratulate myself in having attended, as I have said, the first annual meeting of this society, and also that I have been privileged to be here at the latest meeting, tonight.

The meeting then adjourned.

## CENTRAL STATION ECONOMIES

W. L. Abbott, M. W. S. E.

*Read October 22, 1909.*

The selling price of electricity in large quantities is now about one-tenth as much as twenty years ago, and as the business of selling electrical energy twenty years ago was a precarious one, whereas stock quotations indicate that this same business at the present time is on a safe commercial basis, despite the greatly reduced prices, which are tending steadily lower, it is apparent that radical changes have been and are still being made in central station economies.

Most of the veterans in the electric lighting business easily recall several epochs in the methods of generating and distributing electrical energy, among which may be mentioned that period during which series arc systems predominated, followed by low-tension direct current generation and distribution; later high frequency (125-cycle) generation and distribution; still later low frequency (25-cycle A. C.) generation by engine-driven generator and distribution, after transformation by rotary-converters or motor-generators; and last, the appearance of the greatest of all modern triumphs in prime movers,—the realization of a practical steam turbine of high speed and efficiency and in sizes which would never be feasible with reciprocating engines.

With the improvement in the general scheme of generation and distribution, has come a much more wonderful and unprecedented increase in the volume of business, permitting and necessitating more elaborate organization and a minutely detailed analysis of all of the elements contributing to the cost of the energy sold, so that it is possible for the wholesale manufacturers of electrical energy to tell with as great exactness the cost of each element entering into the grand total of the expenses of conducting the business, as it is for a manufacturer of any other staple article to tell the cost of each piece which his shop turns out.

The items which go to make up the total cost of central station operating may be generally classified as fixed charges, general expense, and operating costs, of which fixed charges equal the other two combined. Fixed charges comprise interest or dividends on investment, sinking fund or depreciation, taxes and insurance, and are the severest burden on the business. An extravagance or error of judgment in design and construction, becomes a tax on the business until that investment is wiped out through the operation of the sinking fund.

Most of the earlier plants were of such irrational design and cheap construction that the depreciation ate up the wide margin between revenue and operating costs, and the fixed charges, instead of being fifty per cent of the total costs of conducting the business, must have been as high as seventy or eighty per cent, or in cases

where the system broke down under excessive fixed charges, they may have been as high as ninety per cent.

Fortunately, now that the day of high prices for electrical energy is past, the business has gotten upon a conservative basis, the different components of the cost are better understood, and the engineering is done by experienced engineers. With the increasing investment in these properties, the capitalization of former errors and of old time apparatus, now obsolete and discarded, is becoming a smaller component of the entire capital, so that the effect, in time, will be to materially lessen the relative importance of the item of fixed charges; and it is by the reduction of fixed charges, rather than by reductions in the amount of general expense or operating costs, that the decrease in the cost of electrical energy in the immediate future will be obtained.

On the other hand, because it is not feasible to construct a pole line for a single wire nor a conduit line for a single duct, and because all installations of whatever nature must have some provision for future growth, as well as for reserve capacity to guarantee the service in case of accident, it is evident that the investment must always be far in advance of the minimum requirements, and to that extent be unprofitable. This is particularly true in a community like Chicago, which has a broad plain to spread itself over, and whose people delight in living as far from the loop district as fast trolley cars and fast trains can carry them in the time which they can devote to travel, or between the hour when the office or shop closes and the hour of the evening meal.

This practice of the people of Chicago is indulged in with no consideration for the fact that in compelling the lighting company to follow them with its lines to their remote subdivisions, they are also compelling it to pile up its investment for pole lines and conduits through intervening miles of truck farms, which some day may be populous districts, but at the present time, so far as the lighting company is concerned, are barren stretches, where its invested capital lies dormant.

The number of power houses which will most economically serve a given market depends on several factors,—extent of territory, amount and density of business, overhead or underground transmissions, and the permissible voltage.

At the beginning of the era of consolidation of smaller lighting companies and power houses, great economy was realized in operating costs by shutting down the smaller scattered plants and supplying the entire territory from one large central station. This saving was due partly to the higher efficiency of the larger apparatus and partly to the relatively smaller operating force required for the larger units. Such savings, however, occur relatively less and less with the size of the power house, and in those having a capacity of 50,000 kw. or over are practically negligible, providing the power houses are ideally located. Unfortunately, however, it is seldom feasible to distribute power houses throughout the territory to be

served, in the way which will result in a minimum of investment and of operating costs.

To provide space for the inevitable future extension, for coal storage piles, and for necessary track space, requires a tract of land equal in extent to several city blocks. It must, of course, be located where it can obtain an abundance of free water for condensing purposes. It must have direct connection to at least one, and preferably two, coal railroads, that term meaning railroads along whose lines coal is mined, so that the freight charges will not be increased by switching charges, as would be the case if the coal originated on some other road and had to reach the power house over the rails of the road upon which the power house is situated. Only those who have looked the city over for building sites which will fulfill these requirements, realize how few of such properties can be obtained, and while the engineer may make an X on the map to indicate the ideal center near which the power house should be located, the real estate man makes another X on the map, probably several miles remote, to indicate the nearest property available.

Next to the fixed charges the largest single item of expense is that of fuel, and as central station systems increase in size and as the business in their ramified circuits builds up, the fixed charges will relatively decrease and the operating costs will become correspondingly greater. One of the keys to cheap electrical energy in future years, therefore, will be an abundant supply of cheap fuel. The desirable coal lands of the country are being rapidly acquired by speculative holders or large corporations, and for future protection any large consumer, who requires the amount of coal which the central station company in a large city does, can well afford to protect itself against the probable and apparently inevitable rise in the price of coal which the increasing demand for fuel and the consolidation of coal properties will bring about.

The consumption of coal by the central station company in any of our larger systems is equal to the output of one or two fair sized coal mines, but as large power houses usually burn an inferior grade of fuel, which is much cheaper than the standard grade, and as this grade of fuel constitutes but one-third of the output of a coal mine, the central station company cannot well afford to own and operate its own coal mines unless it is prepared to go into the business of selling the standard grades of coal on the market. It might, however, effect a partnership or working arrangement with a coal selling concern dealing in the high grades of coal, or with a railroad company, most of which now own their own coal lands and do not find it feasible to use in their locomotives the inferior grades of coal which their mines produce. Therefore, an additional condition might be added to the specifications for a desirable power house site, viz., a site in connection with a railroad upon which cheap coal lands may be purchased.

Having acquired a power house site of ample dimensions, conveniently located in relation to the center of gravity of the load, adjacent to free water and accessible to the rails of two or more coal producing railroads, the subject of power house design is next in order. It should be borne in mind that a power house is primarily an establishment where coal is to be received and burned in enormous quantities, and the refuse to be quickly and conveniently removed, and moreover that of all of the money sent to the power station in pay envelopes, one-half is placed in the grimy hands of those honest sons of toil who handle and burn the coal. The controlling feature, therefore, in power house design should be to cheaply handle and efficiently burn the great tonnage of coal which must go through the boiler room every day. A car of fine coal, when standing over the receiving hopper, may be unloaded by hand for five cents a ton, and it may appear to some that this is cheap enough, but if this cost can be reduced to two cents or less by the use of unloading machinery, the resulting saving on a consumption of 1,000 tons a day is not negligible, even in a large power house.

A vigorous fireman, with nothing else to do, may be able to fire ten tons of coal a day on a plain grate, and this, on a consumption of 1,000 tons daily, with some allowance for the load being irregular and with some further allowance for a few additional men to take the place of those who might not show up when their shifts begin, would require say 125 firemen,—a small army of a class of help which it would be difficult to subject to that degree of discipline which would be necessary for the efficiency required and for the security of the service.

The advent of the chain grate stoker, with its perfect adaptability to Illinois screenings, makes it possible for one man to burn ten times as much coal as is possible with hand shovel stoking, and, not only that, but the fires are run much more evenly and at a higher efficiency. Smokelessness now is considered feasible and necessary in all new boiler installations. Such combustion can be readily obtained by the use of chain grate stokers, but is absolutely out of the question with hand firing.

Formerly boilers were rated on the basis of 12 square feet of heating surface per boiler horse power, and it was supposed that the engineer who ran his boilers at a higher rate to some extent took his life in his hands by doing so. Later, with the general introduction of the water tube boiler, the boiler rating was changed to one horse power for 10 square feet of heating surface. Recent tests and recent practice have shown that not only is a boiler not injured by working it harder, but the efficiency of the boiler and furnace is almost always improved thereby. Therefore, we now find our boilers equipped with tall stacks or with forced draft apparatus or with both, to make a fire over the entire furnace grate of the intensity of that in a blacksmith's forge. To work a boiler 50% above rating is normal condition, and to work it 100% above rating is not unusual. In some power houses the engineers resort to the expedient of in-

stalling a furnace under each end of the boiler, and thus work both ends against the middle.

As was stated before, the power house is a huge establishment for the burning of coal, but it must also be borne in mind that the coal is burned for the purpose of transmitting its heat, by means of steam as a carrier, to the turbine or engine, where the heat is converted into mechanical energy. This transmission is carefully protected throughout its various steps to guard against possible losses, but between the cup of the boiler furnace and the lip of the turbine blade there is many a slip and many a spill; and with all the refinements and improvements known to steam engineering and adopted in power house work, we must admit in our best practice, 86% of the heat of the coal is wasted and only 14% converted into useful work under best test conditions, and only 12% is saved under best operating conditions. The greater part of this loss is unavoidable, and it is, therefore, all the more necessary that all possible minor leaks be stopped. The following table shows how this is true:

One pound of coal equals 10,000 B. t. u.

Ash pit .....	300	
Stack .....	1,960	
Banking fires .....	560	
Radiation and unaccounted for .....	800	
<hr/>		
Total boiler room loss .....		3,620
Rejected to condenser .....	4,810	
Pipe radiation, etc. ....	370	
<hr/>		
Total turbine-room loss .....		5,180
Delivered to busbars.....		1,200
<hr/>		
		10,000

From this it may be seen that 48% of the energy brought into the boiler room passes through the turbine and into the condenser without doing mechanical work. This loss is unavoidable with a condenser operated at the temperatures now employed in the best steam practice. If the condenser temperature could be reduced to about —500 deg. F., much of this loss could be avoided, but, obviously, this is impossible, as this would be operating with ice instead of with steam and water.

Another means of reducing the losses in power plant operation would be to use gas engines instead of steam engines or even steam turbines, but the savings effected by the increase in economy are more than offset by the greater fixed charges due to the comparatively greater cost of gas engines.

The loss at the bung-hole is unavoidable, but some of the spigot losses may be avoided in whole or in part, and as the net amount

saved is small, any additional savings effected will add a respectable increment thereto. To this end the fires are run at the highest temperature that the furnace brick work will stand. All possible precautions are taken to prevent the infiltration of air through leaks in the setting. The steam is super-heated to prevent its condensing during its discharge through the turbine blades. The steam pipes are protected with the best of non-conducting covering, to prevent radiation from high temperature, the latent heat in the exhaust steam from the auxiliaries is all returned to the boilers through the feed water by being condensed in the feed water heater, and the vacuum is kept at the highest possible point by the use of large condensers and unlimited volumes of cooling water.

The most striking, as well as the most important improvement in power house apparatus in recent years, and the improvement which, to a great extent, has made possible the reduction in the selling price of electrical energy since its introduction, is the substitution of the steam turbine for the reciprocating engine. The old and time-honored piston engine, which has been the handmaid of industrial development through the past century, has probably reached its highest possible development and largest practicable size in the four-cylinder horizontal-vertical engine, and any further increases in the size of the unit would result in a prohibitive increase in its cost. This was in part because the weight and external dimensions of the apparatus must increase in a greater ratio than the power of the engine.

The ponderous mechanism, enormously expensive and requiring a huge building to house it, is uneconomical at loads above or below its rating, and, therefore, was a great charge upon the expense of the business, both because of the fixed charges and of the operating costs. The piston speed of these engines, which has gradually been increased from a few hundred feet per minute up to nearly 1,000, nevertheless permitted only of a comparatively slow revolution of the shaft, necessitating a generator of great weight and dimensions. The advent of the steam turbine, with a rotor having a speed ten or fifteen times that of the shaft of the reciprocating engine, permitted a corresponding decrease in dimensions and weight and a material decrease in the cost of the prime mover and of the electrical generator. This of itself would be sufficient to warrant its adoption in the place of the piston engine, but most fortunately the efficiency of the new prime mover was greater than that of its predecessor, and its economy was practically constant over a wide range of load.

Steam engines in large sizes cost approximately 10 cents per pound; steam turbines, 30 cents, but the relative weight per kilowatt are 286 and 34 pounds, respectively, so that the relative costs per kilowatt are about in the ratio of 2.8 to 1. The generator of a large engine-driven unit weighs about 80 pounds per kilowatt, and of a turbo unit, 21 pounds, and their costs are approximately pro-

portioned to their weights. Engine foundations cost \$3.00 per kilowatt, and foundations of turbo-generators about one-sixth as much.

With such comparative costs it is not surprising that the turbine has superseded the piston engine in the design of new, large power houses. An additional reason for this is in the greater capacities possible in single units, turbines now being constructed for 14,000 kw. generators; and it is probable that in a few years they will be made for 25,000 kw.

As a steam turbine exerts its power through the effect of unconfined steam blowing against curved deflecting blades, it is not at once apparent why its efficiency should be greater than that of steam acting expansively in a cylinder against a tight piston, where no leaks exist. As a matter of fact, the piston engine is more efficient than a steam turbine as far as it goes, but unfortunately, it is not practical to expand the steam in a piston engine to more than say twenty times its original volume, and at that point it is exhausted into the condenser with the loss of that power which would result from all possible expansions below say five pounds of absolute pressure.

With the turbine, however, its best efficiency only begins at the point where the piston engine stops. The turbine can and does get the full benefit of the expansion of the steam down to the lowest point obtainable by the largest condenser, and if this highest vacuum obtainable is one-half inch atmospheric pressure, or say one-fourth of a pound absolute, it means that the steam has expanded to nearly 700 times its volume. The object, therefore, of getting a vacuum of the lowest pressure obtainable is that as the absolute zero of a pressure is approached, any slight decrease in pressure will make a great difference in the number of expansions which the steam undergoes. Thus with a vacuum of 28 inches, the volume of steam would be doubled if the pressure were reduced to 29 inches, and would be doubled again if the pressure were reduced to 29½ inches, which is an obtainable vacuum in winter, when the cooling water has a temperature in the neighborhood of 32 deg. F.

One of the important economies which must not be overlooked in such a discussion as this, is the economy of labor. I do not consider it highly important to get cheap labor, but it is essential in a modern central station system, where equipment costing enormous sums is entrusted to employees, many of whom are miles from their supervising officers, that they be loyal to the employing company, have a fair degree of intelligence, and, in most cases, of education, and above all that they be trustworthy. To get and retain in the service such a class of men, makes it necessary that recruits to the force, in most branches, be of promising but untrained material. It will be necessary to instruct them

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in their duties, teach them as much of the principles of the branch in which they are engaged as they will readily absorb, show them a definite line of promotion to which they may aspire, and to avoid as far as possible starting in new men over the heads of ambitious older men in the line of promotion.

Such men are amenable to discipline, take pride in their work, and are proud to be connected with such a prosperous and progressive concern, in whose prosperity they feel that their own future is intimately connected.

The greatest of all extravagances in connection with the central station business are the results of accidents which shut the system down in whole or in part for a longer or shorter period of time. The capital invested is necessary to build up and run the business, but without the confidence of the public, invested capital cannot earn dividends. It is, therefore, imperative that the greatest of diligence and foresight be exercised in guarding against all possible contingencies which may affect the continuity of the service. A single shut-down which would put the theatres in darkness, which would stop the movement of the surface cars, which would prevent our great dailies from issuing their regular morning edition—a single shut-down which would produce any one of these or any similar effect would be a calamity which would work untold injury to the station business; and any expenditure, amounting to millions of dollars if necessary, or any preparation and drill of the operating force which would give reasonable security against a single one of such accidents would be money well expended.

To keep the equipment in prime condition and the operating force at the highest point of efficiency is, therefore, of the greatest importance. This means, therefore, the generous recognition of loyal and efficient service from the employes, or prompt discipline or removal for the opposite reason. It means that the prompt and remorseless abandonment of equipment to the scrap pile, regardless of its first cost, the moment it can profitably be supplanted with newer and better designs; protective devices and methods to guard against probable and improbable contingencies. Eternal vigilance and activity and unstinted yet carefully considered expenditures are the price of success in the manufacture and distribution of electrical energy, and are the prime factors in central station economy.

The distribution of the costs referred to in the earlier part of this paper is approximately as follows:

Fixed charges . . . . .	50
General expenses . . . . .	20
Operating . . . . .	30

## DISTRIBUTION OF OPERATING COSTS.

Generating Costs.	Per Cent.	
Operating payroll . . . . .	6.1	
Fuel . . . . .	20.8	
Supplies and Repairs . . . . .	4.8	
	<hr/>	31.7
Distributing Costs.		
Battery and Sub-Station operation and maintenance . . . . .	12.1	
Street system maintenance . . . . .	12.2	
Reading and maintenance of meters . . . . .	6.8	
Free lamp renewals . . . . .	16.6	
Free maintenance of other current consuming apparatus . . . . .	12.9	
Free wiring and free repairs to customers' premises . . . . .	7.6	
	<hr/>	68.3
Total . . . . .		100.0

This item shows that coal is the largest item of expense and free lamp renewals the next in size.

## DISCUSSION.

*Mr. J. G. Wray*, M. W. S. E. (Chairman): Gentlemen, I presume it is the duty of the chairman to enlarge upon the most important points brought out in the paper, but I am sure you will agree with me that it would be presumptuous on my part to attempt to do so. I was very much impressed, perhaps because I am not a power engineer, by the tremendous development of the Commonwealth Edison Company. It was not many years ago when we were considering generating units in hundreds of horse power. We are now considering them in thousands of kilowatts. It is a striking thing to know that a single unit at the Quarry street power station is today, I believe, larger than the Harrison street plant of the Edison company. It is even more striking to consider the size of these units that *Mr. Abbott* has prophesied for the future—the 25,000 kilowatts unit. Now may be I am going to make a misstatement of the facts, but it is my impression that such a unit would be of sufficient capacity to carry the terminal business of all the railroads in Chicago. Is that an over-statement?

*Mr. Abbott*: You mean of the steam railroads?

*The Chairman*: Yes, the steam railroads.

*Mr. Abbott*: Well, two might do so.

*The Chairman*: Two might. Well, even two. I would not call that a very serious over-statement of the facts.

I was also impressed by the statements showing the very large

economies that have resulted from the development of the art. This fact was impressed upon me quite strongly and in a rather funny way recently. My wife called my attention to an advertisement of a washing machine, and one of the claims in the advertisement was that the total cost of power for the week's washing would be about two cents. Now when we consider that we pay the laundress two dollars, it emphasizes the cheapness of electrical power in a striking way.

But when we are talking about economies, we must not forget the tremendous economic advantage that a company like the Commonwealth Edison Company enjoys. We must consider that three of the most important factors in generating electricity are granted to them. Cheap coal—the author laid emphasis on cheap coal—we householders like the sound of the word. He also spoke of free water. He might have added free oxygen, free air. No wonder they can generate cheap power.

I trust that you will pardon my attempt at levity, and permit me to call on Mr. R. F. Schuchardt, electrical engineer of the Commonwealth Edison Company, who will open the discussion.

*Mr. R. F. Schuchardt, M. W. S. E.:* Mr. Chairman, there is very little that can be added to the very complete and interesting analysis that Mr. Abbott has given us, and which he has very aptly termed Central Station Economies. There is one point, however, which I would like to emphasize, and that is the fallacy of competition, which Mr. Abbott has clearly explained, or, rather, conversely, the *logic of centralization*. And this applies to almost all public service utilities. The chairman will say it applies to the telephone business, and no doubt it does. It certainly applies to such business as urban traction, the gas business, and, most of all, to power producing business. As it is true of these separate utilities, it is all the more true of such a combination of them as can be effected; that is, a combination of all the electric utilities as electric lighting and power and electric traction. The economy of centralized production is due to the diversity factor. If these utilities manufactured their power separately, each must have sufficient capacity to take care of their maximum demand, *plus* (if they are working on proper lines) a sufficient amount for reserve. That means that the item, which Mr. Abbott has clearly shown as being of greatest importance, namely, the fixed charges, is high. Now it happens that these different classes of service do not demand their maximum amount at the same time, so if you bunch them all together, that is, centralize the power production, you get a higher load factor than any of them could have singly, and this means that the fixed charges will be spread over a greater output, lessening the cost per unit of output. Thus the reserve can be common for all.

You undoubtedly have seen the many advertisements which show that in the past few years the cost of electric light in Chicago has been reduced 40 per cent. You all, of course, know that

in that time the Commonwealth Edison Company has taken over the larger part of the power production for the street railway companies. Therein lies the main reason for the lowering of the cost. It enables the company to use large and very economical generators, and to obtain the advantages of the diversity factor and the common reserve. The more large business, and especially the more high load factor business, that the central station succeeds in getting, the lower will be the rates to every individual householder. The lowering of rates, which affects every electricity user, then results from centralization, and when this fact is fully understood the tremendous fallacy of competition will be appreciated and the demagogue's cry against monopoly will cease to win serious attention.

*Mr. A. Bement, M. W. S. E.:* As I sat here I thought of the growth of electric business in Chicago, and am reminded of some early experiences. About the time the first dynamo started in Chicago I was employed by some people who operated an engine and boiler in the building located where the central telephone exchange now is, in Calhoun place. It was an 8 by 16-in. engine and furnished power to tenants in that building. It was my work to fire the boiler and run the engine. My employer came in one day and said that some people were looking for a place to install a dynamo and get power to drive it, as they wanted to start an electric light business, and he was quite hopeful of getting the job of running the dynamo off the 8 by 16-in. engine, in addition to taking care of the factory load. The prospect did not materialize, however. So I missed the chance of operating probably the first electric light plant in this city.

A short time after, in fact, while I was at the same place, General Grant, who had just returned from a tour around the world, visited Chicago. While he was here some people who had installed an experimental electric plant in a basement in Calhoun place quite close by, in a printing office building, operated two arc lights at 111 Madison street, at a saloon run by Lawrence & Martin. There was a light at the front and one in the rear. The plant operated for only a brief period. The scheme was promoted by a Dr. Hirsch, I believe.

In reference to the items on the chart, showing the distribution of heat in the boiler room, it occurred to me that the item of 800 B. t. u., or 8 per cent for losses unaccounted for, includes blowing of safety valves, blowing down boilers, steam used for blowing the dust off the tubes, leakage, etc. The leakage is perhaps very small, but it may be something. A portion of the losses in some steam plants would be incomplete combustion of gases. The radiation probably does exceed 2 per cent or  $2\frac{1}{4}$  per cent—probably not over 2 per cent when the boilers are operated at high capacity. The percentage of radiation is very large when a boiler is banked and doing no work, because it is under steam, as the loss in quantity is practically the same as when a boiler is in operation, thus

radiation from banked boilers is chargeable to those in operation.

One thing which I think has contributed very much to reducing the cost of production of electric current is the better utilization of the boiler house investment. If a plant is operated at the normal rating of a horse power for 10 square feet of heating surface, the fixed charges will be twice as much as would be if the boilers are operated at the rate of a horse power for 5 square feet. This is something that has contributed very much to reducing cost. It is, of course, true that the efficiency of heat transmission is affected by the increased capacity, and that it is not quite so high, but it is a small matter when we compare it with the reduction in fixed charges.

*Mr. E. N. Lake, M. W. S. E.:* To follow the lead of the last speaker, I was thinking, while he was reminiscencing, about the growth of the distribution system of the company which Mr. Abbott represents. Mr. Insull, in his talk before the Electrical Club last Wednesday, said that the company had fifty-four stations and substations, and as I remember it, the larger number of them are substations. Those of us who were with the Chicago Edison Company a few years ago do not find it necessary to think back very far to the time when there were two substations—one in a little hole somewhere up on North avenue, not very far from Sedgwick street, in which I think there were two 125 kilowatt rotary converters furnishing current at 110 volts on a three-wire system; there was another down at Twenty-seventh street. I am not sure, but I think that one was a 250 kilowatt machine. That was not so very long ago; not much more than eight years, I am sure. Now the system comprises some 1,200 or 1,500 miles of high tension transmission cable and fifty-four stations. There is one question that has occurred to me, and that is whether Mr. Abbott has any figures which he is willing to give upon the cost of gas engines per pound and the weights per horse power or per kilowatt.

*Mr. Abbott:* I have no exact figures, but it is my impression there is about the same ratio of difference between the gas engine and the steam engine that there is between the steam engine and the turbine.

*Mr. Lake:* One other question, and that is as to whether there are in operation in Chicago any exhaust steam turbines.

*Mr. Abbott:* There are none.

*Mr. R. H. Kuss, M. W. S. E.:* In most meetings of this character there is always one element that seems to divert the discussion into one relating to smoke and smoke prevention. In some ways that is a little unfortunate, as it brings us too close to our business.

The author has, however, touched upon a large topic, even though it does not necessarily mean that every one is going over to the Commonwealth Edison Company to buy electric energy. If it were not for the fact that people are constituted so that they require heat in order to live in the winter time, there would be more

hope for purchasing power from central stations, even at long distances. One of the chief considerations that lead people to put steam power plants into buildings and factories is that at certain times of the year they must still generate heat in boilers and transmit it by steam pipes throughout the building. The central station has not yet made the price of electric energy low enough so that we can afford to install electric heaters throughout our buildings. When that time comes, we will probably do away with the greater source of the smoke producing chimneys in the city. The alternatives seems to be that of central stations of smaller capacity located in city blocks, the same station supplying the light and the heat for the buildings. This is exactly, to a smaller degree, what Mr. Abbott has brought out in connection with generating power.

Probably the most important subject in the city of Chicago today is the proposed and desired electrification of the railway terminals. All of us, or at least many of us, are a little in the dark about the whole matter, and the thought has occurred to me that perhaps we are working along the wrong lines. The idea of creating a central station for the generation of electric power and putting that current into a transmission line, then carrying that into a motor seems a little cumbersome to me. I should think we ought to expect to see developed a large self-contained unit, a powerful one—just as powerful as the steam locomotive is today, or perhaps a little more so. This is not exactly the city's propaganda in the way of electrification of the terminals, but inasmuch as everybody seems to be a prophet I want to be one just a little different from anybody else, and that seems to me to be the ultimate solution of railway electrification.

*Mr. W. E. Keily:* In speaking of the large gas engines, Mr. Abbott said that they increased the fixed charges. I would like to know if those fixed charges take into account the absence of the boilers; that is, if the gas engine is to be compared with the engine and boiler together.

*Mr. Abbott:* That is my understanding. I want to qualify anything which I may have said about the gas engine, with the statement that I have had no experience with such engines myself; but from statements which I have heard made by those who have had to do with them, despite their recognized efficiency of fuel, they are enormously expensive because of the fixed charges incident to them.

*Mr. Pearson:* I would like to ask what the increase in demand for electricity has been in recent years, due to the use of electric cooking utensils?

*Mr. George H. Jones:* This is a hard matter on which to give exact data, although the amount of electricity used for heating devices and electrical appliances of all kinds is considerable. We have had many calls for electrically heated flat irons; in fact, during the last year we have put out over ten thousand of them. The

income from each of these irons amounts to between fifty and seventy-five cents per month. In addition to flatirons we have a great many heating devices, such as toasters, heating pads, etc. We have at present about 100,000 customers, a good share of whom use appliances of one sort or another, so the total income from this class of business is considerable.

There is one thing I would like to add and that is in regard to the matter of electric power. I am very much interested in this part of the business. In the last four or five years our power load has increased enormously. I can remember only a few years ago when our total power load was about 40,000 H. P., and it was considered very large. We now have a connected load in motors, in addition to our large railroad load, of about 150,000 H. P. A few years ago we considered an installation of 100 or 200 H. P. of considerable size. We are now taking industrial power customers, whose load is as high as between two and three thousand horse power.

One item that was mentioned was that of heating. In factories where the output of power is large, the amount of heating required in such a small item as compared with the total power required as to be of no moment.

*Mr. B. E. Stroh:* The discussion this evening has been very interesting to me, but it is a little out of my line. I see by the map the street system cost shows figures 125 as against the operating of boiler and engine room payroll cost of 61. That makes me think possibly we, in our department, are a little more important than I thought we were. On the question of distribution of current from central stations, I was somewhat surprised by Mr. Abbott's statement that the cost of the distributing to the remote sections was so high compared with the construction of stations in these sections, but that probably is due to the fact that the distribution system includes the necessary substations and converters at the other end.

*Mr. D. W. Roper, M. W. S. E.:* The question of electric heating interesting to know that our largest customers of electric heating are the railway companies—surface and elevated. On two days last winter, when conditions, except as to temperature, were practically identical, one day there was an outside temperature at which virtually no car heaters were required, and on another day in the same week, due to a sudden drop in temperature, was such that they were all required—the difference in the railway load was about 12,000 kilowatts, which I think will very considerably exceed the amount of the heating load from all other sources in the city.

Another point that might be brought out is the question that is frequently raised, why the central station companies do not locate their stations at the coal mines? That is a somewhat complicated question, but the point that Mr. Abbott made of the cost of trans-

mission per kilowatt per mile has a very strong influence upon it. Even if we had overhead transmission, which would be only say one-third or one-fourth the cost of underground transmission, it would only enable us to go three times or four times as far as we could with the underground transmission for the same price, and that would not take us to the coal mine.

*Mr. E. F. Smith, M. W. S. E.:* In looking over the development of the system of the Commonwealth Edison Company it is only necessary to go back to 1897 to find a system with no substations, the largest and best generating station in the West, practically in the country, being the Harrison street station, with a capacity which was scarcely greater than that of several of the individual substations at the present day. There are now upwards of fifty substations, as has been commented upon, about thirty-five of which are the property of the Commonwealth Edison Company, and the remaining fifteen are railway substations. Although the total railway substation capacity is approximately equal to that of the Edison substations, there are only about one-third as many of the former substations, containing approximately half as many machines.

There are no noteworthy features that I will take the time to refer to now, as they have been already brought out in previous discussions. The question was raised by one of the speakers in regard to the necessity of providing for heating as being an obstruction to the central station companies in getting business, which was very pertinent. It occurred to me, as that statement was made, that the very important fact is emphasized in Mr. Abbott's charts, that we waste in the condenser upwards of 48 per cent of all the energy in the coal, and that this lost energy might perhaps in the not remote future be economically applied in doing some of this heating. We heat up the circulating water now and discharge it into the river, and while it is not a new subject, it is one which might be capable of development some time, as tending to solve that problem.

*Mr. F. W. Bernhardt:* I would like to dwell for a moment upon the last remarks of the preceding speaker. The subject of central station heating is a growing one. There has been organized in the state of Ohio, just within a few months, the National District Steam Heating Association, or National Central Station—I have forgotten the exact title—but it is an organization of central station managers and operators who are taking up the subject of steam heating in connection with the operation of electric plants. Of course, it is confined principally to small plants, but Mr. Smith very forcibly called attention to the enormous loss in the condenser that Mr. Abbott referred to. Now would it not be possible in a large city, such as this, for instance, to develop a large central station near the central portion of the city, for instance, such as the Harrison street station, on the plan of utilizing the exhaust

steam for heating the office buildings? I am inclined to think that such a plan would practically eliminate the isolated plants that we have in quite a number of office buildings in a city such as this. Of course, it probably would entail the substitution of reciprocating engines in place of the turbine, because the turbine, to which Mr. Abbott called attention, is particularly efficient when operated with a condenser, and if the turbine was not used, the fixed charges on the plant necessitated by the use of large engines would, of course, be increased tremendously, so that a plant of that kind would be a very expensive one in original cost. The question, however, that comes up in my mind is whether even that increased fixed charge would not be offset very largely by the great return from the heating alone, the exhaust steam, as well as by the increased load that would be obtained in a great many buildings that are not provided with central station service of any kind.

*Mr. Abbott:* I think that such a utilization of the latent heat of exhaust steam would suggest itself to any one situated near a large market for steam for heating, but the complications which it would involve and the difficulties to be overcome in conducting low pressure steam through pipes in the downtown streets would be sufficient to condemn the scheme. Possibly when we have the subway there may be provision made for steam pipes, but such pipes laid under our pavements and among the great mass of underground structures now in the streets would be a continual source of annoyance and expense, and I, for one, should shrink from being responsible for the successful working of such a system. The subject as outlined by the title to the paper is one regarding which volumes may be and have been written. It is impossible for an ordinary person to say anything new on the subject, but if there is one thing which I would emphasize from the discussion of the evening, it is the fact that it is not alone to the operating engineer that we must look for a continued reduction in the price of electrical energy. Such reductions when they come, and they will come, will be due more to improved methods, improved apparatus, and, above all, to a more careful consideration on the part of the designing engineers in laying out systems that will be permanent through a long series of years instead of becoming obsolete in a few years, as in the past. If the electric lighting business is coming to a permanent basis, and it apparently is, apparatus installed now may be considered sufficiently efficient to warrant its continued use for ten or may be fifteen years. The period of competition in electric lighting is past and the period of municipal regulation is here. Those two considerations will tend more to reduce the price of electric energy than any refinement which may be obtained by more careful and skillful manipulation of the fires in the power house or by the supervision of the operating force within and without the generating station.

# MACADAM ROADS AND THEIR PRESERVATION.

L. W. Page, Director.

*Presented November 3, 1909.*

## MACADAM ROADS.

The term "macadam," which is at present applied to all types of broken stone roads that have no paved foundations, is more or less of a misnomer. The macadam road of today is so different in methods of construction from those used by McAdam that his specifications are hardly recognizable.

The use of broken stone on roads is of unknown origin, and probably antedates history. The first written specifications for a broken stone road that I have been able to find are contained in a report by a French engineer named Tresauget, in 1775, which preceded McAdam's and Telford's work by nearly forty years. Not only did Tresauget give a number of specifications and cross-sections of different types of roads, but in the same report he outlined for the first time a plan for a continuous system of maintenance of broken stone roads which is followed to a great extent by the French government today.

I might say that I had the pleasure last summer of seeing Tresauget's original report, and in that report he gives the most carefully drawn cross-sections of these different types of road, and even shows the planting of trees on the sides of the road and the road we call the Telford road today, designed by Tresauget, as I have just said, forty years before Telford built a road, and Telford never built any such road with a curved foundation and the stones placed at right angles to the direction of the road.

The principles involved in the proper construction of a modern broken stone road are, first that there shall be a suitable thickness of stone to give a rigid foundation, and, at the same time, that the sub-grade shall be so shaped and drained that no water can accumulate at the base of the road. The wearing surface is generally constructed of smaller stones than those used for the foundation, and is usually cemented together by the screenings of the rock used in construction, or, when this is not sufficiently cementitious, earth or clay is frequently used. This type of road, when properly built of suitable rock, and maintained, has withstood the wearing action of horse traffic in a most satisfactory manner. When the rock of which such a road is constructed is suited to the volume and character of traffic to which it is subjected, just enough fine dust is worn off by horse traffic to supply that removed by wind and rain, and, by this continuous action of cementing and recementing, a smooth, impervious wearing surface is retained.

The introduction of motor traffic, however, has completely upset these conditions. The pneumatic tire wears off no fine rock dust to cement the surface of the road, but, on the contrary, when traveling at high speed, it throws the dust derived from horse traffic into the air and quickly disintegrates the surface. The exact action of the pneumatic tire on the road surface is still a matter for investigation. We hear much of the vacuum, or suction, produced by this type of tire, the shape of the car body, etc., and, undoubtedly, these factors have something to do with the lifting of the dust from the road and its dissemination. If the road, however, is properly constructed of suitable stone, there should be little or no superfluous dust, and the fault then lies not so much with the shape of the car body and the suction of the wheels as with the construction of the road. I have been conducting some experiments along this line during the last few years, and I am convinced that the greatest destruction to the road surface from the pneumatic tire comes from its shearing action.

In one series of tests, I had a high-speed car driven over a macadam road, which was in first-class condition, at speeds from ten miles an hour to sixty miles an hour, with regular increments of increase of speed of ten miles an hour. The dust raised from the surface of the road by the driving wheels of the car increased directly with the speed of the car, while the dust from the front wheels showed practically no increase. I hope to show you later a series of high-speed, right-angle photographs taken of this car at the different rates of speed, which I believe will illustrate this point. I had no dynamometer for testing the horse power of this car at the different rates of speed, but, as near as I could compute from the rating of the engines and the cross-sections of the car, at sixty miles an hour it exerted a shearing stress on the surface of the road of about 137 pounds per driving-wheel tire. When we have such a factor of destruction as this, it seems to me that any vacuum that could be formed by the wheels would be insignificant in its effect.

With this problem before us, and a rapidly increasing motor traffic, the highway engineers throughout the world are at present investigating every known material that gives the slightest promise of meeting the conditions that confront us. At present, the problem seems almost insurmountable, because materials that will withstand motor traffic are nearly all objectionable, in many ways, to horse traffic, and, with 2,155,000 miles of road in this country and an annual expenditure of about \$30 per mile per year, how are we to construct our roads for withstanding motor traffic, even if we do not consider horse traffic?

#### PRESERVATION OF MACADAM ROADS.

The preservation of macadam roads is undoubtedly the most important problem that at present confronts the road engineer, and one which has attracted more general attention on the part of road

builders and road users than any other. The effect of modern traffic upon the road itself is coming to be more and more severe every day, and the problem is gradually resolving itself into the question of how to modify the ordinary type of macadam so as to produce a more permanent roadway. In regard to the matter of the increasing motor traffic, Mr. Fletcher, of the Massachusetts Highway Commission, with his experts, made one week's census of the traffic passing over the different state highways, and he had some 230 stations on which count was kept and the average motor traffic amounted to forty-eight per cent of the total traffic on the state highways. It is probable that the near future will present an even more serious phase of the problem, due to the use of heavy self-propelled 'busses and vans, which will exert a much greater shearing stress upon the road surface than the lighter motor cars, and, in addition, will subject the whole road, including the foundation, to strains which it was never designed to withstand. This condition of affairs has already made itself apparent in England, where traction engines hauling trains loaded with merchandise to be distributed in the suburbs of large cities are coming into general use.

I hope we will use every endeavor to keep them off our roads. They are on our rural roads now that have never been constructed, and of course cannot do those any harm, but I am afraid they will get on our improved roads and will simply ruin them.

Disregarding this aspect of the problem for the time being, and considering it only as it is presented today in this country, we may briefly review the methods which have so far been employed to meet it, and, I believe, forecast the probable outcome of the whole matter in a general way.

As the primary cause of road destruction is due to the removal of the finer products of wear, the most promising method of solving the problem of road preservation seems at first thought to lie in the treatment of the road surface with some material which will prevent the displacement of the rock dust in the wearing surface. Water alone is known to serve this purpose to a certain extent by developing the cementing value of the rock dust, but its action is but temporary owing to its rapid evaporation. Applications of sea water which contain small quantities of hygroscopic salts produce perhaps a little more permanent effect, but result in an accumulation of inert sodium chloride in the road surface, which, for a number of reasons, is undesirable. "Bittern," the mother liquor obtained from the evaporation of sea water in the manufacture of salt, being slightly richer in these hygroscopic compounds, is somewhat more efficient, but its use is quite limited, and will probably never prove satisfactory. Solutions of calcium chloride, which keep the road in a moist condition for a much longer time than water alone, have so far given more satisfaction than any other salt solutions, but even calcium chloride, which is one of the most hygroscopic salts known.

requires an occasional feeding with water, unless the atmosphere is particularly humid. This means that it can never be used successfully on the majority of country roads, where no convenient supply of water is at hand.

Working along the line of dust retention by moistening, experiments were conducted in Algiers a few years ago with cheap vegetable oils which could be readily applied to the road. More permanent results were obtained than from the application of water, but the road surface was made so slippery that their use was abandoned. The same effect is produced by the application of mineral oils rich in paraffine, or oil and tar distillates, which also act to some extent as lubricants, which, while holding the dust down, tend to destroy its binding qualities, and thus aid in the disintegration of the road surface. The lighter oils and oil emulsions containing a certain amount of true binding base have proved much more satisfactory where properly applied, as have also tars of suitable consistency. Their use has certainly been a step in the right direction, inasmuch as an actual binding medium has more lasting qualities than the simple rock-dust bond.

The same may be said of concentrated waste sulphite liquor from wood pulp mills, which produce an even more powerful bond, probably due to the tannic acid present, but which is somewhat less permanent in effect, owing to the tendency of rains to dissolve and remove the binding base from the road.

It is not within the scope of this paper to consider all of these materials in detail, but merely to mention typical examples with relation to the part they now play and will continue to play in the solution of the problem of macadam road preservation. When employed in the surface treatment of roads, the best of them will prove effective for only a comparatively short time, owing to the fact that, as the road surface wears down, they are rapidly removed or their binding value becomes inert. They must therefore be considered as temporary binders which will have to be applied at more or less frequent intervals, according to local conditions. As a class, they will continue to be used in the treatment of old road surfaces for some time to come, both as dust preventives and road binders. In the resurfacing of old roads and the construction of new roads, however, their use will probably never prove satisfactory or economical, for in such cases the defects in the ordinary macadam road will merely be repeated, and a temporary remedy applied for a chronic trouble. Need for a modification of the ordinary form of construction is here made apparent, and, in the light of our present knowledge, the solution of the problem would seem to lie in the use of some form of bituminous binder of sufficient strength and durability to keep the road intact as long as the wearing surface exists. Many experiments have been tried along this line with different bituminous preparations, and the most variable results have been obtained. Some few successes have indicated the possibilities of

the bituminous macadam road, and many failures have evidenced a lack of knowledge on the part of experimenters of the requisite characteristics of bituminous materials for work of this nature, and often a complete disregard of the probable effect of certain unmistakable properties upon the road when subjected to service conditions.

To deal with this phase of the subject in a satisfactory manner would require more time than I have. The bitumens would have to be classified according to their properties and use, and the effect of their various chemical and physical characteristics discussed at some length. In general, however, it may be said that the bitumens suitable for construction work consist of refined water-gas tars, coke-oven tars, gas-house tars, residual oil products holding an asphaltic or semi-asphaltic base, oil asphalts, and native asphalts, and gilsonite fluxed to the proper consistency with a suitable carrying medium.

Binding value and consistency are two of the most important features to be considered with reference to the use of bitumens in road construction, and, strange to say, these features have, in the majority of cases, been overlooked. The bitumen, as it exists in the road, should have the consistency of a semi-solid, and, if such is lacking in the original material, it should have the property of hardening to the proper consistency, after being applied to the road. Most of the failures that have resulted from experimental work can be attributed to the use of fluid bitumens which after application remain in a fluid condition in the road, allowing the upper course of stones to creep and deform under traffic, producing a soft, sticky surface condition in warm weather by continually sweating and oozing upward.

There are two general methods of constructing bituminous macadam roads, each of which offers certain advantages. They are known as the penetration method and the mixing method. As commonly employed, no attempt is made to bond more than the upper two or three inches of stone with the bituminous material, as this has in most cases been found sufficient. Preference should undoubtedly be given to the mixing method, but its cost is usually somewhat greater, and for this reason it has not been generally adopted.

The penetration method consists in pouring hot bitumen upon the upper course of stone which has been well rolled and partially filled with clean stone chips not smaller than  $\frac{1}{2}$ " in diameter. The lower course should be firmly consolidated and its voids well filled with fine material before the upper course is laid, in order to prevent the hot bitumen from running through to the road bed. Application is made of approximately one and one-half gallons per square yard, since the object is to use enough to thoroughly coat the upper course of stone. The surface is then painted with hot bitumen at the rate of not over one-half gallon per square yard, and clean sand, or stone

chips free from dust spread on in sufficient quantity to fill the surface voids and take up all excess of bitumen, after which the road is consolidated and made smooth by rolling. After this it is advisable to close the road to traffic for a day or two in order to allow it to set.

The principal disadvantages of this method are as follows:

(1) It is almost impossible to obtain an absolutely uniform distribution of the bitumen. This results in the accumulation of the binder in pockets which are apt to produce soft spots, and in some portions of the road the individual stones are not sufficiently well covered to produce a satisfactory bond.

(2) It is necessary to use more bitumen than is actually required to coat the road stone and bond them together.

(3) It is difficult and sometimes impossible to employ a bitumen of sufficient original consistency to produce a satisfactory bond, owing to the fact that such bitumens congeal too rapidly, when applied to cold stone, to insure a proper penetration. The bitumen must, therefore, have the property of acquiring the right consistency after application.

On the other hand, this method has the advantage of being easily and rapidly carried out. No costly apparatus is required, and the labor item is comparatively low.

In the mixing method, a roughly graded broken stone aggregate is first coated with hot bitumen and then spread to a depth of two or three inches upon the foundation course. After being thoroughly rolled, this course is painted with hot bitumen and covered with sand or stone chips as described under the penetration method. The process of mixing may be conducted either by hand or by mechanical mixers, and with either cold or hot stones, preferably the latter. Instead of separating the crushed stone into various sizes and then mixing the different sizes in given proportions, it is often possible to utilize the crusher run of material from 2-inch size down to dust, thereby considerably reducing expenses. Other things being equal, that mineral aggregate having the lowest percentage of voids after being applied and rolled should produce the best results. About 6% of bitumen should be employed in the mixture, and this will usually prove to be less than that required in the penetration method.

The disadvantages of the mixing method as compared to the other two are as follows:

(1) The cost is as a rule somewhat greater.

(2) With the same labor force, work can not proceed as rapidly.

(3) To obtain the most economical results, more elaborate apparatus is required.

It has the advantage, however, of producing an absolutely uniform road in which the bitumen is evenly distributed throughout the upper course and covers each individual fragment of stone. Work can be successfully carried on during colder weather than is

allowable for the penetration method. If hot stone is employed, a bitumen can be employed of such original consistency as will be required in the finished road to satisfactorily meet local conditions.

Where suitable binders have been employed, satisfactory roads have been constructed according to both methods. In these roads the mineral aggregate is so firmly bonded that the surface is capable of successfully withstanding the strains imposed by automobile traffic, and, at the same time, the wear from horsedrawn vehicles is greatly reduced owing to the increased resiliency of the road. The ordinary macadam has been so modified that the products of wear are not essential to its life, and, in fact, its life is increased by reducing wear to a minimum. Hard rock, having no cementing value of its own can be utilized to advantage in such roads, and less depends upon the character of road stone than in the case of ordinary macadam.

As traffic conditions become more severe, it is probable that a further development of the bituminous macadam will take place relative to the construction of the foundation course. A cement grouted foundation will in all likelihood be substituted for the old loose stone foundation, which is bonded simply by the mechanical interlocking of the various fragments, and this may be eventually superseded by a mixed cement concrete foundation. All indications point to an evolution of the broken stone road and toward what may be more properly called a pavement, where the limiting factors are the cost and the character of the traffic to which the road is subjected. One fact is at least certain, that the day of the macadam road is rapidly nearing its end. It has served its purpose for many years, but new conditions are insistently demanding a new type of road, and, if it is to exist at all in the future it will have to be modified in some such manner as has been described.

#### DISCUSSION.

*President Allen:* I want first to thank Mr. Page for giving us this paper and also to express our appreciation of the substantial way in which the government service is taking interest in these matters and co-operating with the engineers of the country, and with the engineering societies. I am sure we are very glad to see representatives of the government service at any time, and we are more than glad to hear from them, discuss what they bring us, and try to exchange ideas with mutual benefit.

Mr. Page did not show illustrations of the roads in a large district of the state of Illinois known as Egypt. I have traveled along these roads in the early spring and wish I had some photographs of them. I think that he has come to a state that needs his services and his advice.

*Mr. A. N. Johnson, M. W. S. E.:* In discussing the modification, if you may call it, of macadam construction, it occurs to me that some of us have gone ahead and left out of sight the inherent prin-

ciple of a macadam road, and have abandoned what we learned in the construction of such roads and are proceeding along more or less experimentals, perhaps to find ourselves obliged later on, to go back to some of the things that we have learned in the past. For instance, the main strength of what holds the macadam road together is the mechanical bond or interlocking of the pieces of stone that go to make up the road. Just to the extent that we tend to destroy that bond we have a weaker road surface. For instance, it is suggested in the mixing methods of applying bitumens to macadam construction that we shall take various sized material, coat it with bitumen, put it down on the road and roll it. Now, what is the result? We inevitably have close to a larger size of material, a smaller piece of material wedged in, and some of the void is taken up with our semi-plastic binder, and in the end we have a roadbed, not with the stones jammed together to keep together, as when we set the sizes in the usual method of making a macadam road, but a road that is not as strong as it would be with the pieces locked together. When we pour over the top of the road the semi-plastic binder we have not damaged the initial strength of this construction, but the sticky mud on the wagon wheels pulls out our top binder, leaving the top stones exposed to the action of traffic, so that they will easily loosen. It seems to me that if we are going to have a macadam construction we should not lose sight of those principles that we have already learned, and in applying any binder, we should see if we can not apply it in such a way as to keep that strength of road and get the effect that we want to have. Of course, it may be found that in many places the motor traffic will be so severe as to demand other kinds of construction, and we shall have to abandon the macadam road, but that seems to be far away for the ordinary country traffic. If we are to abandon the macadam construction at all, I think we will certainly come down to some form of pavement leaving out entirely the idea of a plastic binder, and have it either of brick or well constructed concrete or something of that sort which will resist the auto traffic and is least expensive to maintain.

I think the point in keeping on with the macadam construction is not to throw away all we have learned in that form of construction, in attempting many of these newer methods. I have seen some of those methods tried. Where the traffic is distributed entirely over the road, there perhaps is no noticeable difference between the construction used and one that might be firm, but when you concentrate the traffic, as in ordinary country practice, and which is the most severe condition that you meet in any road work, with traffic going practically in one line, then in any road that is not solid, or that has the least tendency to yield, you will find a squeezing and rolling action. This can not be prevented, unless the road has the inherent stability that will allow absolutely no movement of any of the particles that go to make it up.

*Mr. Page:* What Mr. Johnson says is true. Everyone has gone mad over bituminous binders during the last few years. The number of trade names for the same thing is so great that they require a dictionary, almost, to contain them all. They have even gone so far that a great many of these men who have the sale of different bituminous materials have claimed impossible things for them. We are running away too fast from the real principles that we know in road construction; the old macadam construction is good if we use the best knowledge that we have on the subject. Where automobile traffic is too heavy for it we must use a stronger binder than the natural rock dust.

*Mr. A. W. Woodman, M. W. S. E.:* I think it might be interesting if Mr. Page could tell us something about the comparative cost of preserving our American roads by the method of a treating process and the cost of preserving macadam roads as they are maintained in France. In his paper the author speaks of roads as originally designed by Tresauget, and I judge from his paper that the roads are maintained somewhat along the lines which were laid down by that French authority. If so, it would certainly be very valuable to know whether our difficulty is not this: that we are trying to maintain our roads for a long period of time by a single process, whereas it might have been intended, with the road as it was designed, to maintain it by a continuous process.

*Mr. Page:* The subject of cost of maintenance is a very interesting one and one very hard to get any accurate information on, but I have been to a good deal of pains in the last two years to collect as much accurate information as I could on the comparative costs of maintaining different roads in the different European countries. I am afraid to trust my memory on exact figures, but they are about as follows:

England has no system of maintenance at all. Each county council, or each borough council, or each vestry has supervision over its own roads, makes its own contracts, uses whatever methods it wants to, and to a considerable extent they use pauper labor for maintaining their roads. I remember twelve years ago going over England trying to get information along these lines from country surveyors, and in county after county I would ask the cost of maintenance and would get ridiculously low figures. I would take the matter up item by item and when it came to the cost of labor, I would be told it did not cost anything, that "we use pauper labor." I said, "I think that is the most expensive type of labor you can use." But now road organization has been brought about to some extent, and they have collected some very accurate figures within the last few years. On the principal trunk line roads in England and some suburban roads the cost has gone up enormously, as 80 per cent to 100 per cent in some cases, which shows the effect of the automobile traffic on the road. It is costing on the most important roads in England as much as \$620 per mile per year. That

is maintenance alone. Remember, in this country, we are spending for maintenance and construction only about \$30.00 per mile a year on an average.

In France, where there is a perfect system and everything is planned for ahead of time and all estimates made, it is costing in no case over \$340 dollars a mile a year, and France has the lowest cost figures of any country where maintenance is really carried on.

Now the matter of maintenance in this country is only being considered at the present time. We have never had any heretofore.

New York State has just adopted a system of continuous maintenance, the patrol system, and the Highway Commissioner told me recently that they had obtained better results than from any other one thing they had done. Their roads seemed to be just as good now as they were when first built. But aside from New York there is not a state in the Union that has any continuous system of maintenance. Many of them have built roads a number of years, and they build them in patches with the hope of finally making a continuous line, but before those roads are connected the first of them will be worn out and they will have to begin and build them over again.

*Mr. C. T. B. Goodspeed:* I am much interested, generally, in the matter of streets. There are two or three that I would like to mention. This suggestion of Mr. Johnson's about putting his larger stones on top and smaller ones underneath reminded me of some specifications that affect the President and certain other of your members, because they live on the street where they are just about to do such work, there I noticed that very thing, that the stone to be put at the bottom is to go through a two-inch ring and the granite on the top is to go through a three-inch ring. This is an entire change from what was supposed to be proper years ago. I wanted to ask for an explanation of this change.

There is another thing that I do not understand. Nowadays when they build a macadam road they put granite on top instead of limestone. We have in the parts of the city I am most familiar with, a lot of old limestone macadam roads that seem to the lay mind to stand up fully as well as the granite-surfaced roads, and yet nowadays the granite surface is put on. I should like to know why the granite surface is put there. Is it because it is harder or what is the advantage? The South Park Commissioners have just been doing a lot of macadam resurfacing and I believe it has been done in the way you were just describing. It is something of that bituminous nature worked through the top two or three inches. Some of you may know what that is.

*Mr. Page:* I think there are two distinct reasons for putting the granite on top. One is, that it is a good deal harder than the limestone, particularly the limestone in this locality, and when a bituminous binder is used it makes a more enduring macadam road. It has the advantage that when limestone is mixed with a highly

siliceous rock, like granite, the cementing value is enormously increased and it will form a better bond. For instance, a limestone giving a cementing value of say 20 and a granite giving a cementing value of 89 are mixed together, you will get a cementing value sometimes as high as 130 or 140.

In regard to Mr. Johnson's suggestion of inverting the macadam road, I think that where only a soft rock is available and a clay foundation has to be dealt with, it is an admirable idea to put the large stone on the top. As an illustration of it, I might mention an experience of the Massachusetts Highway Commission. About fourteen or fifteen years ago, when they were building a road on the island of Martha's Vineyard, they struck quicksand, and dumped load after load of rock into it which disappeared. There was a good deal of consternation, and one of the commissioners, who was not an engineer, made what seemed to be an absurd suggestion, that unbleached cotton be spread over the quicksand and the stone put on top of it. He was laughed to scorn, but he finally said that he would pay for the unbleached cotton if it did not work. So they sent to a neighboring town and got several bolts of unbleached cotton and spread it over this quicksand, and then covered the division lines with another layer, and then dumped a load of stone on it. It settled down about 0.75 to 1 inch and stopped. The driver backed up his cart with much caution and dumped some more stone, and finally found he could drive his cart right over it. The steam roller operator did not want to go on it, but finally did so. I went over that road last summer, and it had not settled at all.

I think that on a clay subsoil small material at the bottom ought to have something of the same effect, and I would like to ask Mr. Johnson if that is the case. Another point: I think where you have to use a very soft stone, by putting the smaller material on top it is ground into dust too quickly.

*Mr. Johnson:* That was exactly the reason that we turned the sizes upside down or turned the road upside down. First, we had very poor material as compared with what is used in the best roads. Rock limestone, most of it, is friable, and if the smaller pieces are used on top traffic will soon pound it into dust, and it is a fact that when you have the smaller pieces in the bottom they crowd up the larger ones. I am confident many of our roads would have been cut through if they had been built in the ordinary fashion with the larger pieces in the bottom. It is nothing new with us, merely a new statement to a certain extent. Every macadam road that is made is necessarily arranged that way just to the extent that you seat the pieces of stone. Of course, you may start with a layer of large stone and then on top put a layer of small stones. I would do that myself if I had very hard rock to work with. But in that layer of stone there are various sizes of pieces. The minute you disturb them the large ones tend to work up to the top, like a basket of potatoes when you

shake them up. There is a tendency for the large stones to come to the top, and when they are at the top then you have what I call the natural equilibrium of the pieces relative one to another. If there is any further disturbance in the road, and it tends to loosen up, the pieces in the bottom won't come through for the big pieces are on top. Look along a road in the springtime: the stones loose on top are the big ones. It is not the little ones you see where there is a disturbance of the surface due to the traffic. If there is a larger stone underneath it will work up to the surface every time. In a paper presented before the Society October 21, 1908, I brought up this idea. Spread your road material, then harrow it to disturb the pieces until they so distribute themselves, that the smaller pieces are at the bottom and the larger ones on top. I did not make that quite as strong in the paper as I should have done. For the work we have done this season we have had good, solid harrows made that weigh about 350 pounds. A team easily draws them up and down over the road. Such work does not knock the shape out of the road, but simply stirs up that material until it gets in the natural position. It settles the material down and more thoroughly than any amount of rolling could possibly do in the same time.

*Mr. A. C. Schrader, M. W. S. E.:* Consistent, however, with the suggestion made by Mr. Johnson, of placing small stones at the bottom of macadam pavement, and the larger ones at the top, I may relate an experience in laying a macadam pavement in this city, in the year 1896. The foundation of the street to be improved being entirely of clay, a portion of the roadway was covered with stone, ranging in size from 2 to 2½ inches, in the largest dimension—the intention being to finish the macadam roadway in the manner customarily followed in this city. The frequent rainfalls during the progress of the work caused the clay foundation to become quite soft, so that the rolling of the surface with the steam roller proved entirely unsatisfactory, as it simply churned up the materials to such an extent that the roadway could not be brought to a surface sufficiently unyielding to receive the finishing material of granite macadam. To obviate the difficulty and to enable us to complete the work without delay, I made the experiment of using a layer of cinders 4 to 6 inches in depth, spread over the clay, and forming a subgrade. Upon this the crushed stone was spread and rolled in the usual manner, and we were able to finish the work satisfactorily and without delay; the cinders apparently acted as a mattress, directly overlaying the clay and preventing the churning up of the clay and stones as heretofore mentioned.

The use of the ordinary macadam pavement in our cities and suburbs, where automobile travel is heavy, will, of necessity, become more limited unless a better form of construction is devised. It will become more limited because engineers will find that while the first cost is low, no high degree of excellence, as to surface, can be maintained. The various treatments to which macadam pavements are

subjected in an effort to obviate the breaking up of the roadway surface, such as oiling of roads with crude oil, or with emulsions of oil, or superficial tar mixtures, are little more than temporary in their results. Where the density of traffic is such as to warrant the expenditure of money sufficient to construct a more permanent form of wearing surface for the pavement, a consideration of a bituminous macadam may be made; and in certain cases asphalt may be used with economy, laying it on an existing macadam surface of proper depth and stability.

*Mr. O. P. Chamberlain, M. W. S. E.:* I think that it will be a very long time before the macadam road is abandoned in this country. I mean that roads will continue to be built with a macadam foundation. Now, our trouble with the macadam road is almost entirely with the top surface. What is necessary in a macadam road, provided we have sufficient material to produce a solid foundation, is that the top surface should be drained and that it should be so cemented together that it will not be rapidly worn out by traffic. We have obtained fair drainage, previous to the advent of the automobile, by simply cementing our top surface together either with limestone screenings or some similar material, or a binding gravel composed of gravel, loam and clay. As has been stated here, the automobile brought in a new problem. The automobile traffic tears up this cemented surface. Now what road builders and street builders are striving to do is to replace the upper surface of the macadam with something more positive in its binding nature. The experiments that have been tried have been largely in the use of tar products and asphaltum. My own limited experience in the use of bituminous macadam, so called, has been with the spreading of it, or the tar, on the surface, and while we do not know how permanent these pavements will be, I think fairly good results are obtained, both in the matter of drainage; that is, you get a surface which readily sheds water—and in the matter of the surface being not easily displaced by the traffic, because of the presence of prepared road tar in the upper three inches of the road. In this process you finish your macadam road just as you would an ordinary limestone macadam, and then spread your top coat, preferably, I think, all about of a size and not smaller than two inches. I see Mr. Page does not agree with this. He says to put in half-inch chips, but I have found if you put in half-inch chips before you put the tar in you do not fill the interstices between the stones with the tar. I have tried both ways. By pouring the tar very hot, then coating with chips from three-quarters to one-quarter inch with the dust out, rolling again, and then again, as Mr. Page has stated, spreading with a light coat of tar and covering with about one-quarter inch chips and rolling, we get a very good surface. How permanent that surface is or will be, I have not had experience enough to know.

*Mr. Linn White, M. W. S. E.:* This subject is very interesting to me, and it is one on which I have recently spent a good deal of

time; that is, a great deal of my work has been in that direction. Like all the rest of us that are engaged in making a living that way, we accumulate a good deal of experience as we go along. I think I know more about it than I did a year ago, and hope a year hence I will know still more. But some things have been said that set me to thinking, and possibly I may add something that will be of value—at least something that was running in my own mind and may be of interest.

I have read at different times, with a good deal of interest, Mr. Johnson's suggestion as to the use of the large stones, or, rather, the reversal of the small and the large stones, and have listened to Mr. Page's relation of circumstances where some sort of a mat was used. All of these, I should take it, would be mere expedients in the matter of construction. Ultimately I believe that if we are to get a macadam road, or a road made of broken stone (by whatever name we please to call it), that will be in itself an engineering structure, we must treat it with the same idea in mind that we have in any other engineering structure. If we build a bridge, it is made up of component parts; if we build a brick wall or a stone wall, it is made up of component parts; but just so long as these component parts do not act in proper relation with the other parts, we do not have a good structure, and an excessive strain may, from time to time, come on the individual parts. If we cement a road together so well, whether it be built of large or small stone, that it acts as one structure, then I think we have a suitable and substantial road. Now unquestionably, in practice, we cannot build that sort of a road if we use too much fine stone, and if we use all fine stone we shall never be able to bind it together. We may be able to take advantage of the natural cementing qualities of limestone or other stone that has cementing qualities, but the harder and more durable the material we use, as a rule, the less its cementing value. Speaking of the material we have here in Chicago, available for our road construction, it is practically confined to two materials—limestone and granite. We have not the advantage of the trap rock which is a most excellent hard road building material and at the same time has a high cementing value. But by the use of the two materials mentioned we get two different valuable qualities, the cementing quality of the limestone and the durability of the granite. But the point of view has much to do with this, or I should say the point of experience; that is, the kind of traffic that we have to contend with. I have been through that section of the country which has been alluded to as Egypt. I know something of it, and know something of the character of the country. I have been to a place down there that was named Pull-tight, and I think there is no better named place in any part of the country. There undoubtedly we have to reverse the order of proceedings to build a road, and some expedient must be resorted to to overcome the natural disadvantages of such cases.

But getting back to the point I was speaking of, the construc-

tion of the road, if we have the materials bonded permanently together, so long as we hold it there, we have a structure that acts as a complete unit and not as separate or disintegrated parts. Granite has been used to a very large extent in Chicago for the surfacing of the road, evidently for the reason that it has greater wearing qualities, but wherever granite is used we find by experience that we are compelled to use some sort of cementing material like a mixture of clay and gravel, or crushed limestone.

Now, I may refer to some experience we have had in the South Parks system in years past on that point. There have been built some most excellent roads that gave great service for many years, where granite was the top surface, and I suppose they were as good as roads of that sort could have been built; at any rate, they gave long service. But I have in mind one particular instance of the building of a road of that sort about three years ago: we built it according to the best methods we had learned by experience, using limestone for the body of the pavement, fairly coarse, and topping it off with granite. It lasted but a few months. The granite never did become bonded. We never had any benefit of the hardness of the stone. We might just as well have built it of the softest limestone we had. That and similar experiences have led me to the point of saying that it is of no value for us to pay twice as much per cubic yard for broken granite than we do for the limestone; but if we find some method of holding it together, whether it be limestone or granite, we will get more service out of the road. Whether we build a road with large stones on top and small on the bottom or reverse the proceeding, and hold it together, make it act as one structure, I think then we will get the benefit of a scientifically built roadway. The traffic, of course, we have to meet here is decidedly different from the traffic we meet in suburban and country districts; yet Chicago has a great many miles of macadam road all in more or less serviceable condition, according to the length of time it has been in use and the amount of maintenance that has been put upon it. On our boulevards, of course, we spend a good deal more money in maintenance than is spent on many of our ordinary macadam streets, but at the same time we have to meet traffic of a very destructive character. We have at different times taken a census of the traffic over the different boulevards, and we find that at least seventy-five per cent of it is automobile traffic. No matter whether the number of vehicles be 5,000 or 1,000 passing over the roadway, we have practically in all cases about seventy-five per cent of automobile traffic to take care of, and therefore that is our greatest problem to meet.

We have had some experience in using bituminous binders, with the idea of holding the stone together, thus making a substantial and durable surface. We have worked a good deal on the surface treatment method but believe we are getting now the most reliable results out of the mixing method.

There is a suggestion I would like to make, that we should dif-

ferentiate between the pouring method and mixing method by naming them differently. As Mr. Johnson says, we should keep the benefit of the old established methods of building macadam roads. We can get the benefit of them if we use the pouring method. If we use the mixing method we are doing something else. We are then introducing the principles of concrete. I think there should be a differentiation between those two methods of building the road. In one we have macadam construction and in the other we have a concrete construction.

*Mr. Johnson:* Mr. White speaks of the uselessness of the granite on certain roads, and I think he explains it thoroughly by mentioning the character of the traffic that goes over the roads, seventy-five per cent being automobile traffic, and I imagine that this is rubber tired traffic. In other words, there is not traffic heavy enough to grind up the chips into dust. Until the dust is made to combine with the limestone, of course there is no gain in the cementing power mentioned by Mr. Page. On country roads, where we get heavy traffic, heavy in the sense of a large pressure per square inch, sufficient to crush the granite chips, or, what is the same thing, granite gravel, we find that we do get that great gain in binding power by putting on a granite top. In fact, much of the material we use comes from the Joliet quarry. That limestone has absolutely no binding power. We have built a road of that in one or two cases and it bonded at first and seemed to stand well; in fact, went through the winter all right until the spring. The next spring and summer were dry. In October there was loose stone from end to end on the road, showing there was absolutely no permanent bonding power in that dust, whereas with other roads, where we had found out that this limestone dust possessed no binding power and had applied a granite top, they remained in good shape, and we chiefly attributed it to the increased binding quality of the ground-up granite with the ground-up limestone.

*Mr. W. A. Levering:* Mr. Chairman, in looking over Mr. Page's paper I see, in describing the penetration method, he states that he uses one and one-half gallons of bituminous binder per square yard. I would like to inquire, for estimating purposes, the thickness of this top course and whether or not it was found by experience that one and one-half gallons of binder will fully fill the voids in that portion.

*Mr. Page:* I think I have already stated that I do not think practice so far shows that it is necessary to have it penetrate more than about three inches, and my idea in putting the chips or sand on top of the foundation stone to fill up the voids was to prevent the bituminous binder from going down to the base of the road and to prevent pockets of bitumen from forming in the foundation course, and I think that it will be found that if the top surface is well rolled, a gallon and a half of bitumen per square yard is ample to fill the voids.

*Mr. Levering:* That is using say two and a half inch stone down to one-half inch or three-quarter inch?

*Mr. Page:* Yes. Preferably I would use one and one-half inch stone for the wearing course.

I prefer the old screen, three, two, and one-half inch ring. If a foundation course of the largest size is thoroughly rolled and on top of it a second course of the intermediate size, that is, one and one-half inch size, and rolling it thoroughly. I believe when rock is thus used you get more uniform wear and a smoother surface and better lasting qualities, whether you use a bituminous binder or not. Any excess of screenings can be put in the foundation course.

*Mr. Levering:* Would you fill the voids with the bituminous binder?

*Mr. Page:* Yes.

*Mr. Levering:* Completely fill it, flush with the surface?

*Mr. Page:* Yes; for the top three inches.

*President Allen:* We have the pleasure this evening of the attendance of Professor Hayford, Director of the new College of Engineering of Northwestern University. I am sure we would all be very much pleased to hear from Professor Hayford.

*Prof. J. F. Hayford, M. W. S. E.:* I remember seeing a suggestion in the *Engineering News* of a few months ago that possibly the violent action of the rubber tires of automobiles was due to a differential shear, so to speak, between the middle of the tread of the tire and the outer edge. When the tire comes down into contact with the road the middle part of the tread comes down on to the road with a larger radius of motion than the parts of the tire on the outer edge of the tread, and therefore there is a tendency under the tire for the outer edge of the tire to be drawn forward on the road at the same time that the middle of the tire is drawn backward. Now, as presented in the *Engineering News*, it looked as if that brought shearing forces into play that would considerably increase the shearing on the surface of the road due simply to the driving action of the wheel. I would like to ask Mr. Page whether he has considered that theory of the causes of the wear on the road.

*Mr. Page:* Personally I do not believe that that is altogether an essential. In experiments that I made on Long Island the 20th of last May, at which I had a number of types of cars and a number of types of tires, among other tires we used a flat one, and I think, if anything, it threw up more dust than the round one. That very point has been most ably presented by a British engineer, whose name I cannot now recall, but his paper was in the proceedings of the Institution of Civil Engineers of Great Britain about four or five months ago. The subject is gone into most elaborately and a most interesting theory developed, but I do not believe it is borne out in practice. I am arranging now to conduct some experiments along this line and I hope to complete them by next fall. I am planning

first to build a drum dynamometer, and I want to build one that will permit of the testing of the highest power car—that is, up to 150-horsepower—and I am going to use an alternating current generator for a break and an exciter so that I can vary the magnetism. Then I want to have a revolution counter put on both the front and rear wheels of a car, with electrical clutches, so that they can be thrown in and out of gear. With this apparatus I hope to be able to not only determine the shearing force of the driving wheels, but also the slip of the driving wheels.

*E. N. Layfield, M. W. S. E.:* In answer to a question early in the discussion (Mr. Godspeed's, I think), Mr. Page was under a little misapprehension, I believe, as to what the question was. This granite-topped macadam referred to is built as a limestone macadam and finished that way, and then there is about a three-inch granite macadam put on top of that. They are not mixed in any way, and, as I understand the question, Mr. Page's opinion was desired as to the relative merits of the limestone macadam with granite top as described, and limestone macadam without the granite top. In other words, is the road any better for having the granite top on it than if it had a limestone top?

*Mr. Page:* That is a matter of opinion. I should prefer to make a test of the cementing value of the limestone and granite, because they vary so much, but I should say offhand that better results would be obtained if the limestone and granite were mixed than if they were used separately.

*Mr. Layfield:* It would seem to me that the granite would be lacking in the wearing quality that you say is essential to replenish the places left by this dust that has been blown off. That occurs with the proper kind of limestone, and it might be that this granite is too hard to produce that effect.

*Mr. Chamberlain:* The specifications of the city of Chicago call for three inches of granite above the limestone base. They do not depend at all upon any binding qualities of the granite. The specifications also call for bonding with a gravel binder. It is extremely difficult to bond the granites that we use, which are from Wisconsin, with a gravel binder or a gravel and loam and clay binder, and to get entirely satisfactory results. I think Mr. White passed upon that, if I remember, and spoke of their attempting to build a road of that kind. The great difficulty under the specifications of the city of Chicago is to get that top course properly bonded. I am satisfied that the limestone roads built in the vicinity of Chicago and in Chicago, the older roads before the granite top was used, so far as remaining cemented together is concerned, are much more durable than the granite top. There are roads here within fifteen miles of Chicago which I know have been built for twenty years, which were built entirely of limestone and they are in reasonably fair condition now, although there is considerable automobile traffic upon them.

There is another thing that comes to me in regard to the cementing qualities of limestone. The limestone quarries in this vicinity, at least a great many of them, have fissures which are filled with clay between the layers of rock. My own judgment is that part of the binding value of the limestone screenings that come from those quarries is due to that clay, which as the stone goes through the crusher is nearly all pulverized. Probably the stone from the Joliet quarry is free from those clay fissures. It frequently happens, even in stone which comes from this vicinity, that we get screenings which have been piled for some time so that the clay is washed out of them, and in a case of that kind we find it extremely difficult to bond the macadam, so my own judgment is that there is a mixture of clay and limestone screenings which really produces this good bonding effect in the limestone road.

*Mr. Page:* I think that is apt to be the case. In this connection I mentioned awhile ago that you are getting the limestone and the highly siliceous matter combined, which always gives higher bonding effect; but I think it is better, if you are going to put on a three-inch surface of crushed granite, to cover it with, say, a half inch of limestone screenings. If this is done I think you will find the road, if subjected to a reasonable amount of horse traffic, will bond splendidly, better than putting any gravel that you can get on it.

*Mr. Kempster B. Miller, M. W. S. E.:* I would like to ask if the practice of placing on top of a limestone course after it has been rolled a layer of broken granite that will pass through a three-inch ring and not pass through a one and one-half inch ring, and then a layer of gravel sufficient to fill the voids, then rolling, then placing a one-half inch layer of granite screenings and rolling, is now the standard practice in Chicago; and, if so, how long it has been and what results have been secured from it. Is that about the present standard specifications of Chicago?

*Mr. Chamberlain:* Yes, you have stated it about as it is. The top course of granite screenings, what we call the top dressing, I think is of doubtful value as to any increase in wear of the road. The roads that are surfaced that way after about six months or a year do not show much of the granite screenings. It has always been a question in my mind whether we were getting any better results by using granite at all on top of the streets here in Chicago.

In regard to the durability, it depends almost entirely upon the character of the traffic. I think out on the South Side, in the Englewood section, for example, you will find some of the best granite top macadam roads that have been in service for a number of years, that we have in Chicago. However, the traffic there is light; the streets are residence streets and they get very little automobile traffic. They get principally carriages and grocers' wagons and comparatively light traffic. There are streets in that section of Chicago which have been in service for seven and eight years that are in very good condition.

The granite top macadam does not stand automobile traffic very well. I had occasion last spring to resurface a road on the South Side which is in the direct line of traffic between Jackson Park and South Chicago. The road was built two years ago, according to the city of Chicago specifications, with granite top, bonded with gravel. The gravel and the fine particles on the top of the road had been completely torn up. The granite had not been picked up to any great extent, that is, the granite which formed the wearing surface of the road, from three inches to one and one-half inches in size, but the finer particles had all been picked out and a good deal of it was down in the gutters. The road was resurfaced by picking up and using the same granite, with some additional bonding gravel. The trouble with the granite which we use here, which is entirely Wisconsin granite, seems to be that we have not been able to find the material that will give it a good mechanical bond.

I do not know whether the specifications have ever been changed. I do not know how long the present specifications have been in use, but to my knowledge they have been used for the last eight or nine years without any change. Whether they have ever tried bonding this upper course of granite or not with other material than gravel or limestone screenings, for instance, I cannot say. I would be inclined to be of the same opinion as Mr. Page, that if that were permitted we would probably get a more permanent surface.

*Mr. W. H. Dean:* I would like to speak of a little experiment the city has made on a macadam road subject to heavy automobile traffic. The experiment is about two years old, but at the same time has stood the test splendidly and I think would show up a little differently from what Mr. Chamberlain says with regard to the granite top as compared with the limestone top.

Mr. Minwegen, of the Board of Local Improvements, chose what he considered one of the hardest tests in the city on streets under the city control. Evanston avenue, or Sheridan road, as it is known, at Devon avenue, about a quarter of a mile west from the lake, has a limestone macadam surface. Automobiles come down from the north, from Evanston, at a high rate of speed, and here turn a sharp corner. There are street car tracks on a curve on the southwest side of the street, leaving only a narrow roadway in which to turn, and the road is subject to hard usage. The limestone macadam surface was worn through very considerably about that curve, into a deep hole, and a great amount of dust was raised. To repair this, a large size of crushed granite, three or four inch size, was put in, bonded with gravel and loam. It was put in at a difficult time of year in this respect, in that it was freezing weather. It has been down about two years and has worn splendidly. You will scarcely find any dust there and almost no sign of wear. It is a little bit rough, but otherwise it has made a splendid corner. On the rest of the road, except where it has been resurfaced, the limestone has been worn very considerably.

On the matter of bond, I think it is largely the quality of the gravel that is used as to whether it is a proper material. There must be a proper amount of loam in it. On a street with granite top, bonded with gravel, which had been down only a short time, but was allowed to set well before there was any traffic on it, I have picked it open for the purpose of making measurements and have had pieces of hard granite break apart in opening up the street, the bond was so complete.

*Mr. Page:* I might mention, in connection with cementing value, that I cannot see the object in placing gravel, an inert substance, as a bonding agent unless it is mixed with loam. If there is any bonding value obtained it must be from the loam or from the clayey material brought on the surface in some way. Why use expensive material like gravel when you generally have loam on each side of the road, or clay? Clay has the highest bonding power of any inorganic substance available for road building. In Europe they use it as a bond to a very large extent.

*Mr. J. H. Warder, M. W. S. E.:* We have available here a supply of gravel from Joliet, in which the pebbles are mostly of limestone, and the gravel carries a good deal of clay or loam, which makes it a very desirable bonding material for a macadam roadway.

*Mr. Page:* Practically limestone screenings, then.

*Mr. Warder:* It is glacial drift, of medium size pebbles, and carrying a good deal of yellow clay.

*Mr. Page:* I thought it was the lake gravel such as I saw used on the South Park roads. That was very clean angular gravel.

*Mr. Dean:* I would say that the specification on that gravel is that no large stone comes into it; nothing over one inch is allowed and there is very little of that. There is very little stone in it, but that is the way the material comes. It is more of a clay. I would also say that we try to use as little of the bonding material as necessary, just enough to fill up the voids, and in that experiment I spoke of, in regard to the large granite, there was very little bonding material used. I think a large part of the bond there comes from the wedging together of the large pieces, and there is just enough of the gravel to complete a solid body. The gravel or loam sets very hard and has bonding value in itself to hold the stone in place and the large stone wedges itself in place. I favor, myself, large gravel for the large surface stone.

*Mr. Page:* This matter of bonding is one that I thought I knew a good deal about twelve or fifteen years ago, but I had an experience the other day which was completely at variance with my past experience. I witnessed an automobile race at Lowell, Massachusetts, where a boulevard sixty feet wide was treated with angular quartzite gravel and a very good grade of residual oil. I inspected the whole course the day before. During the race the wheels cut right through this one and one-half inch binding surface. Now, with that in mind and the results at Indianapolis, I was asked

to inspect the Fairmont Park track three weeks ago before the race. There were some of the worst curves I ever saw and some on very heavy grades. In going over this track I was much worried to see on the surface in many places nothing but cinders spread over the surface, with a little clay mixed with it and rolled with a steam roller. I was asked did I think the road would stand the wear and tear of the race? I said unless the Almighty intervened I thought there would be some very serious accidents. There were no serious accidents. Five minutes after the race I went slowly around the track and examined it thoroughly, and I believe that ten men in six hours could have made the whole course just as good as it was before the race. That shows you what I know about the subject.

*Mr. Geo. Jos. Bell*, County Surveyor, Cumberland Co., England, (by letter): As macadamized road construction has been, from time to time, engaging the attention of road engineers in America, I venture to give a brief account of the construction and maintenance of the main roads in the County of Cumberland, England.

The first care of a road engineer is to see that the subsoil foundation is quite dry, and, if not naturally so, then it should be made so by cutting a drain up the center of the road from three feet six inches to four feet deep, so as to be safe from the effects of frost, and placing in it four-inch common field drainage tiles, and filling up the drain again in the ordinary way. Suitable outlets should be made in connection with this drain at convenient distances not too far apart.

It should be remembered that the subsoil has to bear not only the traffic but the road surface itself.

Now form the road bed, allowing a fall of one inch to the yard, 1 in 36, from the center to each side, and when this is done, I follow Telford's plan, which is copied from the Roman system, and lay down a six inch layer of handpitching, filling up the interstices with small gravel or broken stone. Pass the steam roller over this in a dry state to find out any slack places, which must be leveled up where shown, and the foundation is then ready for a binding of good rich clay, which ought to be dug out and exposed for a few months before it is required. This must be well watered and rolled till it shows a fairly even surface. On this apply a three-inch coat of broken metal—I prefer it unscreened, just as it comes from the stonebreaking machine.—Give this coat a good binding of clay, and apply water and roll it till the clay becomes a thin puddle, which must be swept about with brooms or brushes till the metal is quite covered up.

Again apply a second three-inch coat of metal and break all large stones, if there are any, with a hammer before applying this coat of metal, as in applying the first coat, every shovelful must be turned over and spread evenly with great care. Apply a coat of binding to this second coat of metal, puddle it well with water and sweep about the road while the roller is consolidating it, and when

it begins to dry spread some fine gritty screenings, about the size of peas, thinly over the whole surface and roll till the surface looks like fine concrete, when the road is finished.

I find that a three-inch coat of metal is as much as can be properly consolidated throughout with a ten ton steam roller, and when so consolidated, and constructed as described above, the road will carry the heaviest traction engine traffic hitherto met with on our roads without showing any signs of yielding, and a road so constructed never heaves through the action of frost, because the surface forms a roof on a dry subsoil, and keeps it waterproof. It is the yielding of a wet subsoil that causes the road to break up and work into ruts.

In repairing a worn road which has become uneven on the surface, the road should be cut across with a pick, six inches apart, and a stone deep, strike the space loose between the cross-cuts, adjust the loosened metal with the rake, apply a thin coating of new finely broken screened 1 inch or  $1\frac{1}{2}$  inch metal, bind with clay and treat as directed above. If the defective parts are in patches, then cut round each patch with a pick, loosen the surface, level up the depression with new metal, bind with clay, water well, and allow the traffic to run it in, if it is too small a job to employ a steam roller on.

The cost of maintenance for the upkeep of such a road runs from £40 to £50 per mile per annum, under the heaviest traffic, including motor cars of all kinds.

A road constructed as described above yields few, if any, loose stones, and a minimum quantity of dust.

Wind, dry weather, and quick moving motor cars are the greatest enemies to the surface of such roads, and to keep these tight and safe a little fine clay ought to be applied where the surface is seen to be breaking loose.

In making a new road from the bottom on the above lines, the cost runs about £1,200 per mile including the making of the road and the fences on both sides, but does not include the purchase of the necessary land.

As long as motor cars are built as they are at present, so near to the ground, and allowed to travel at the present high speed, so long will the public be troubled with dust from any construction of road, and no matter how such roads are treated.

In my opinion the firm of motor builders who will construct motor cars with larger wheels and practically solid tires, with the body of the car at least one foot nine inches from the surface of the road, will command the trade of the future for this class of vehicle.

## THE LAW OF CONSERVATION OF ENERGY.

Dr. Charles P. Steinmetz, Past President A. I. E. E.

*Presented November 16, 1909.*

At this year's visit to your hospitable city, I intend to speak on the *Law of Conservation of Energy*. There are two fundamental laws of nature to which all phenomena are subordinate, the law of conservation of matter and the law of conservation of energy. Of these the former is the older one. Both, indeed, had been stated already by the ancients, but then merely as philosophical speculation. They have been derived as scientific laws based on experience only in recent times—recent as far as the development of science is concerned.

The law of conservation of matter is the older one. It dates back to the early beginning of modern chemistry. When first modern chemistry began, nearly 200 years ago, when first it was observed that gases are material things, can be collected, measured and weighed, then the law of conservation of matter was recognized, and it was understood that the apparent disappearance, by combustion or so, does not mean the destruction of matter but merely a change of shape, of form.

Much later was brought to our attention the law of conservation of energy. Less than a century ago it was first pronounced by men as Ruhmkorff, Mayer and Joule, the English scientist, who made careful investigations which gave not only the law of conservation of energy, but also the numerical relation between the measures of some forms of energy: as heat and mechanical energy. Since that time both laws have become generally accepted as the foundation of science. The law of conservation of matter has become generally familiar even to laymen. There is hardly anybody who does not accept the law of conservation of matter, who does not realize that nothing can be lost. If something has been apparently lost, everybody will tell you it can't be lost, it must be somewhere, even if we can't find it. As to the law of conservation of energy we are not quite as far advanced as yet. It is not yet common knowledge of everybody. We engineers and scientists are familiar with it, accept it, obey it; even the lay public understands it more or less; but still occasionally you hear ideas like perpetual motion machines talked about amongst the uneducated, the idea of producing energy from nothing, which obviously is an impossibility. But even amongst engineers this law of conservation of energy is not yet so familiar that in our engineering practice we have made use of it as a tool, and a very convenient and effective tool, to that extent to which we should make use of it; and even now we occasionally meet speculative theories which, if followed back to their final conclusions, are more or less contradictory to the law

of conservation of energy,—which naturally means that the speculative hypothesis is false, is wrong.

It is therefore that I desire to draw your attention to some uses of the law of conservation of energy for engineering purposes.

The two laws mean: No matter can be created, no matter can be destroyed. It may change its shape or form but it remains always the same in amount. So also no energy can be created, no energy can be destroyed, it can be transformed from one form to another, from electric to magnetic, mechanical, heat energy; but it is always the same amount of energy, although it may appear in different forms, may be measured by different units. Although even in the latter direction we are gradually approaching the time where we measure in the same units. If you read modern books on chemistry you will find that the energy is measured in Joules, the unit of electric energy or work. The only branch of engineering in which this is not yet done in our country, is mechanical engineering. The mechanical engineers still employ the mixture of B. t. u.'s, of kilowatt hours, foot pounds and sundry other units.

Energy can not be destroyed, can not be created; it remains the same; and is merely transformed. At the same time, if we have a fly wheel revolving rapidly and let it run without taking off any energy, still gradually it comes to rest. Its energy has disappeared; apparently has been destroyed. It has not been destroyed. It is still there, as heat in the air surrounding it, in the friction in the bearings, but it has ceased to be available. For all practical purposes it has been destroyed. It has gone to raise the temperature of the universe ever so little. That means while the law of conservation of energy says, that energy can not be destroyed or created, there also exists a second law, that energy may for all practical purposes be destroyed by becoming unavailable, being dissipated as low temperature heat energy. In all transformation of energy we find a loss of energy. Not that the energy has disappeared, but that it has deteriorated in form, as we may call it, changed into a form from which we can not transform it back, and thus can not use it any further.

This is not only a law of energy; we find a corresponding relation in the law of conservation of matter. While matter can not be created nor lost, practically it is lost. Only look back at all the gold which has been collected in the world from the records of ancient times, the treasures collected by Romans, by the Indians and Mongolians, in the middle ages, by the Incas and Aztecs. It all has long ago disappeared. The amount of gold in circulation has not greatly increased. It had even decreased until gold was found in California and Australia, and later on in Colorado, the Klondike, Alaska. So you see that this commodity which by its general utility and by its particular character has received the continuous attention, has after all as available matter been lost—not destroyed, but

scattered, dissipated, brought into a form in which it was just as unavailable as if it did not exist.

As a special law of energy, this law is generally expressed as the second law of thermodynamics, that heat energy can flow without the expenditure of mechanical energy only from higher to lower temperature but not inversely. But this second law, is not only a law of thermodynamics but is a special application of this general second law of nature, that transformations of matter, transformations of energy, are always in the direction of deterioration, in the direction of increasing the amount of lost or dissipated, that is, unavailable energy, or matter. The result, therefore, is that even if for the use of the human race the same amount of material and the same amount of energy would be sufficient, and not an increasing amount with the increase of civilization, we would still require a continuous supply of matter and of energy, to make up for the loss, to make up for the energy which has ceased to be of use by becoming unavailable as low grade heat, etc. For the advance of the human race there is thus required a continuous supply of matter and of energy. Here we are interested only in the source of the supply of energy. We need energy to maintain our life.

The human being and the animal organism, after all, are, physically speaking, nothing but energy transforming machines. They convert the energy of food into heat and into mechanical power. We require a supply of energy in the form of food to maintain life. We receive that from animals or vegetables, by eating the result of animal life or plant life. As animals again live on animals or on plants, if we follow back, we see the energy supplied to maintain our life ultimately leads to the supply of chemical energy in the products of plant life, of vegetation. Plant life thus supplies us with chemical energy in the products of the plants. It receives its energy not as chemical energy, as the animal organism receives it in the food, but the plant receives its energy supply as radiation from the rays of the sun. Plants are converters of radiant energy into chemical energy. They absorb the energy of the rays of the sun, the energy of light, and convert it into chemical energy, which is stored in the products of plant life, and is subsequently used to maintain animal life as food, as the supply of chemical energy. You see, then, at the last resort, our life and all animal life depends for its energy supply on sunlight. This is therefore the most important source of energy, although if we, as engineers, consider the sources of energy it is one we frequently overlook. It is the most important source because our life directly depends upon the energy of the sun's rays which we use ultimately in our food. This is not sufficient, however, for us to maintain our life. We do not get enough heat by the combustion of food. We need to protect ourselves by clothing, by houses, need to heat our residences in the winter, and herefor require energy; for transportation of ourselves, of our food, our building materials, we

require energy; require energy for lighting; require it for all our social, industrial, domestic or other occupations; require, therefore, a continuous supply of energy, which we get by using nature's stores of energy.

We have two large stores, fuel and water power. As regards to fuel as source of energy, we need to consider coal only as the characteristic one, since the other fuels, oil, gas, wood, while considerable in amount absolutely, are insignificant in comparison to the amount of coal which we use. In the coal we use chemical energy. That chemical energy has been stored in bygone ages as the products of plant life, again leading us back to the light of the sun as the source of energy, but in the fuel we use not the sun rays of our generation but of bygone ages before man existed, when the sun shone over the primeval forests.

Then there is water power as a source of energy. Here we use the potential energy of the water which is collected from rainfall on high elevations. It has come down from the clouds. It has risen to the clouds as vapor, evaporated by the rays of the sun from the lower level. Again the ultimate source is solar energy. A minor source of energy is the wind, and it is not entirely negligible. While there is not much energy in it, it is useful as a source of a small amount of energy in pumping, in agricultural service, has possibly been the oldest form in which energy was used; and it is due again to differences in the temperature of the air produced by the rays of the sun which have set the wind in motion. So it is with the waves of the sea. Wherever we look, the source of energy in different form is solar radiation, and those ancients who looked upon the sun as the highest god and life-giver were not so far out of the way.

Incidentally, the only source of energy which is not dependent on the sun are the tides. They use up the stored energy of the rotation of the earth, of the revolution of the moon around the earth and the earth around the sun. The tides do not yet give us any useful energy to any appreciable extent. It is doubtful whether they ever will. The elevation of the tide is altogether too small to amount to anything except where it backs up like in a funnel, under favorable conditions, as on the New England coast where the tide rises to a great height. But even at the highest tidal elevation, after all, the tidal energy is like that of an engine with low pressure piston, because the total pressure even if the tide rises twenty or thirty feet, is only ten to fifteen pounds pressure. But it is a piston making one stroke every twelve hours. You see, with one engine revolution every twelve hours, one tidal rise, it is practically impossible to gear up to a reasonable speed, so that the only use we could make of it is to gather the tidal water in a basin or reservoir to supply a tide mill. The tides are useful also, but we will never run the wheels of industry by them. The sun will remain the ultimate source of energy.

In dealing with these two fundamental laws of conservation, the problems relating to the law of conservation of matter are the field of work of the chemist. In our field, as engineers, belong the problems relating to the law of conservation of energy and its corollary, the dissipation of energy by its becoming unavailable. Also we have to deal with the methods and problems, of converting from one form of energy to another and the study of the loss of energy in the conversion. Here we continuously make use of the law of conservation of energy in tiding us over relations between different forms of energy. If we build an electric machine and desire to find out how successful we have been, how well we have been able to convert the mechanical energy into electric energy, in other words, to measure its efficiency, we do not measure the mechanical input and the electrical energy output. We measure only the one quantity and measure the losses to get the other one. We measure electrical output and losses in the machine and adding them gives us the input, or we measure the input, subtract the losses and get the output. If we would do it otherwise it would be very much more difficult and very much less accurate. Thus you see we are relying upon the law of the conservation of energy in the correlation of the results. We do that throughout all engineering work. If you desired for instance, when designing an electric motor, to calculate its power, theoretically you could calculate the forces exerted by the magnetic field on the current in the armature conductors, calculating the magnetic field intensity at every point of the circumference, and therefrom the force which it exerts on the current in every element of the armature conductors, and the direction of this force, and integrating over all the conductor elements and field elements, and if you lived long enough you might complete such a calculation.

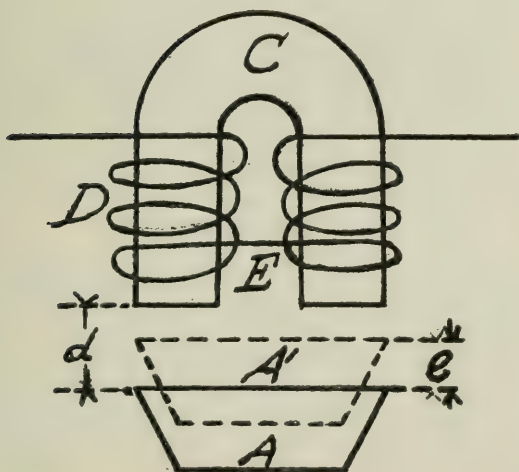
I say theoretically it is possible, just like many other things which are theoretically possible, but practically we can not do it. What we do is this: We calculate what voltage will be produced in the armature conductors by their rotation through the magnetic field, and what current there is flowing. Volts times amperes give us the power which disappears as electric power, and by the law of conservation of energy, this must reappear as some other form of power somewhere else. It reappears as mechanical power, and part of it is consumed in driving the armature through the magnetic field, is lost in the armature, core loss we call it. A part of it is consumed in friction. The rest appears as useful mechanical power. So we see the law of conservation of energy has bridged over between the energy supplied and the different form of energy which we get out of the apparatus. We could in very many cases use some form of this law of conservation of energy to get results quickly and accurately which otherwise we can not get as easily nor as accurately, especially when we have to deal in our engineering work with two different forms of energy. Where we have to

deal only with one form of energy, as only with electric or only with mechanical energy, the laws are very simple, the calculations are relatively simple, and very exact. We can calculate all the phenomena of electric and magnetic forces fairly easily and very accurately. So we can calculate the phenomena of mechanical energy and of chemical energy. Much more difficult it becomes when we have to relate one form of energy to another one, calculate the mechanical forces produced by the magnetic phenomena or the electric energy produced from chemical energy. Here, then, it is where we can use the law of conservation of energy to bridge over the gap between the different forms of energy.

To illustrate, for instance: Take such a simple case as to calculate the pull of an electromagnet.

Suppose  $E$  in Fig. 1 is an electromagnet, consisting of the iron core  $C$  and the magnetizing coil  $D$  of  $n$  turns, wound on it.

Fig. 1.



It is to be calculated, with what force the keeper or armature  $A$  will be attracted, when at the distance  $d$  from the poles of the magnet.

This can be done by calculating the magnetic pull as proportional to the square of the magnetic density  $B$ , the area on which this density acts, etc. etc., but obviously no great accuracy is feasible in this manner without too laborious calculations.

It can be done much simpler by remembering the law of conservation of energy: when the electromagnet  $E$  attracts its keeper, and moves it by distance  $l$ , into position  $A^1$ , it does work. This work is  $W = Fl$ , where  $F$  is the force, or the pull of the magnet, and  $l$  the distance which the keeper has moved. By the law of conservation of energy, this work must have been supplied by the electric circuit, as only available source of power. If then the magnetic flux of the electromagnet in the initial position of the keeper,  $A$ , is  $\phi_1$ , and in the final position, after moving by distance  $l$  to  $A^1$ , the magnetic flux is  $\phi_2$ , the coil on the electromagnet has during this motion cut the lines of force  $\phi_2 - \phi_1$ , and in the coil therefore the voltage has been induced:

$$e = \frac{n(\phi_2 - \phi_1)}{t} 10^{-8}$$

where  $t$  is the time, during which the motion occurred.

The power, consumed in the coil during the motion then is:

$$P = e i = \frac{i n(\phi_2 - \phi_1) 10^{-8}}{t}$$

and the energy consumed thus is:

$$W = Pt = i n(\phi_2 - \phi_1) 10^{-8}$$

As this electric energy represents the mechanical work  $Fl$ , it is:

$$Fl = i n(\phi_2 - \phi_1) 10^{-8}$$

hence, the pull of the electromagnet:

$$F = \frac{i n(\phi_2 - \phi_1) 10^{-8}}{l}$$

This is the average pull on the keeper, during its motion by distance  $l$ , and if we assume  $l$  sufficiently small, make it  $dl$ , thus is the pull in the desired position.

If a civilized system of units of length and force is used, as the metric system,  $F$  gives directly the force; in the English system, the multiplier reducing from absolute values to the English system comes in: if  $F$  is required in lb.  $l$  in inches,  $F$  is given in lb. ins,

hence is  $\frac{F}{12}$  ft. lb. or  $\frac{Fl}{12 \times 550}$  H. P. sec., or  $\frac{Fl746}{12 \times 550}$  watt seconds or Joules, thus:

$$\frac{F \times 746}{12 \times 550} = \frac{i n(\phi_2 - \phi_1) 10^{-8}}{l}$$

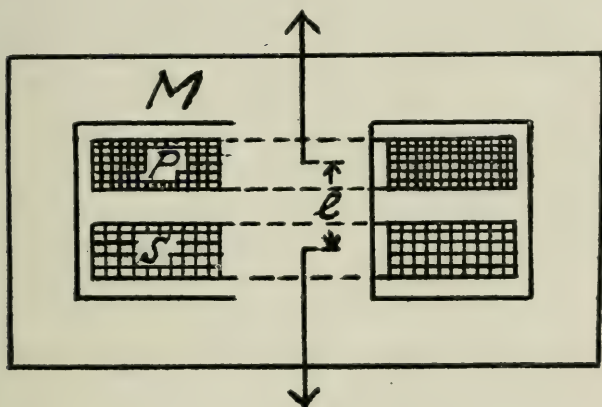
and:

$$F = \frac{i n(\phi_2 - \phi_1)10^{-8}}{l} \times \frac{12 \times 550}{746} \text{ lbs.}$$

In similar manner we may calculate the mechanical stresses in an alternating current transformer under short circuit.

Let Fig. 2 represent diagrammatically the section of an alternating current transformer, with the iron core  $M$ , the primary coil  $P$  and the secondary coil  $S$ . Between the primary and the second-

Fig. 2.



ary coil a repulsion occurs, as the currents in the two coils flow in opposite direction, and under short circuit, in large transformers this repulsion may assume formidable values.

Let  $e$  = impressed e. m. f. of the transformer and  $i$  the short circuit current, that is, the current flowing in the transformer at short circuited secondary and full voltage impressed on the transformer (varying from 10 to 50 times the full load current). If the generating system is so large as to maintain the primary terminal voltage even under short circuit, the magnetic flux passing through the transformer primary  $P$  must be the same under short circuit, as in normal operation (when neglecting the voltage consumed in the resistance of the winding, which can be done even under short circuit conditions in such approximate calculation). No magnetic flux passes through the secondary  $S$ , as it is short circuited (neglecting again the small flux required to give the resistance

drop). That is, under short circuit, the full magnetic flux of the transformer passes as leakage flux between primary  $P$  and secondary  $S$ , instead of around both coils, as under normal operation.\*

Assuming now that we could move primary coil  $P$  and secondary coil  $S$  towards each other, against the repelling forces of short circuit, until these coils coincide with each other. No magnetic flux then would pass between primary and secondary coil, and by this motion by the distance  $l$  between primary and secondary coil, these coils would have cut the full magnetic flux of the transformer, and thereby the electrical work would have been done equal to that of cutting the full transformer flux  $\phi$  at the short circuit current  $i$

During normal operation, the full transformer flux is cut once every quarter cycle, and thereby gives the induced e. m. f.  $e$ , hence

the power  $e i$ , and the work or energy:  $W = \frac{e i}{4 f}$ , where  $f$  is the frequency.

Thus the electrical work, representing the bringing to coincidence of primary and of secondary coil, under short circuit current  $i$ , is  $\frac{e i}{4 f}$ . The mechanical work, however, is  $Fl$ , where  $F$  is

the total repelling force, and  $l$  the distance between the centers of primary coil  $P$  and secondary coil  $S$ . Thus, by the law of conservation of energy:

$$Fl = \frac{e i}{4 f}$$

or:

$$F = \frac{e i}{4 f l} \text{ in absolute units, and, if } l \text{ is given in inches:}$$

$$F = \frac{e i}{4 f l} \times \frac{12 \times 550}{746} \text{ lbs.}$$

For instance, in a 5,000 kw. 25 cycle transformer, if  $l = 6$  ins. is the mean distance between the coils, and the internal impedance of the transformer such, that the short circuit current  $i$  is 25 times the full load current  $i_0$ , it is:

$$e i_0 = 5,000 \text{ kw} = 5 \times 10^6 W$$

hence:

$$e i = 25 \times e i_0 = 125 \times 10^6$$

and thus:

$$F = \frac{125 \times 10^6}{4 \times 25 \times 6} \times \frac{12 \times 550}{746} = 1.84 \times 10^6 \text{ lbs.} = 820 \text{ tons.}$$

That is the weight of a heavy freight train.

\*If under short circuit the impressed voltage drops, due to limited generator capacity the short circuit flux drops in the same proportion.

While this force is distributed over a considerable area, nevertheless it is so enormous, that it is a very difficult problem to design apparatus mechanically so strong as to stand such enormous mechanical strains.

In many other instances, you may apply similar methods of calculating mechanical forces in electrical apparatus and systems by the law of conservation of energy, as for instance, the stresses in reactive coils, in generator armature coils, the forces with which conductor and return conductor of a short circuited feeder cable repel each other, etc.

Even in many instances, where we have to deal only with one form of energy, as with electric, the law of conservation of energy may be used as convenient tool to bridge over more abstruse calculations and derive simple results. This for instance is the case in studying the phenomena occurring during the opening of an electric circuit. An electric circuit stores energy in its magnetic field, that is, by its inductance  $L$ , and in its electrostatic field, by its capacity  $C$ . If  $e$  = voltage,  $i$  = current in the circuit, the electromagnetic energy is  $\frac{i^2 L}{2}$ , the electrostatic energy  $\frac{e^2 C}{2}$ .

If the circuit contains only resistance and inductance, but no appreciable capacity, it can not instantly be opened, since during the opening the electromagnetic energy must be destroyed, and instant destruction of energy represents infinite power. During the opening of the circuit, the magnetic energy is dissipated in the opening spark, by an e. m. f. induced there. The current dies down from  $i$  to 0, thus averages about  $\frac{i}{2}$ . If then the opening of the circuit requires the time  $t$ , the energy represented by the e. m. f.  $e_0$ , which is dissipated at the opening spark, is:

$$\frac{i}{2} \times e_0 \times t$$

and as this must by the law of conservation of energy equal the magnetic energy of the circuit, it is:

$$\frac{i e_0}{2} t = \frac{i^2 L}{2}$$

or:

$$e_0 = \frac{i L}{t}$$

is the voltage which appears at the circuit breaker. As seen, it is inverse proportional to the time of opening.

If the circuit contains capacity as well as inductance, the circuit

can be opened instantly, as such interruption of the current does not require destruction of the magnetic energy  $\frac{i^2 L}{2}$ , but this energy may be transformed into electrostatic energy.

In this case, the total stored energy of the circuit is:

$$W_0 = \frac{i^2 L}{2} + \frac{e^2 C}{2}$$

If the current  $i$  is suddenly interrupted, the voltage  $e$  rises to  $e_0$ , so that the total circuit energy is stored as electrostatic energy:

$$\frac{e_0^2 C}{2} = \frac{i^2 L}{2} + \frac{e^2 C}{2}$$

If the circuit is short-circuited, that is,  $e$  suddenly disappears, the total energy becomes electromagnetic, by a rise of current to  $i_0$ :

$$\frac{i_0^2 L}{2} = \frac{i^2 L}{2} + \frac{e^2 C}{2}$$

This allows a simple calculation of the voltage  $e_0$  which may appear when open circuiting, and the current  $i_0$ , which may appear when discharging an electric circuit.

Opening the circuit at current  $i$  and negligible voltage  $e$  (as for instance, opening a short circuit), gives the voltage:

$$e_0 = i \sqrt{\frac{L}{C}}$$

which, if  $i$  is large, as under short circuit, may be enormous.

Discharging a charged conductor of voltage  $e$ , gives the discharge current:

$$i_0 = e \sqrt{\frac{C}{L}}$$

thus, even if  $e$  is high,  $i_0$  usually does not exceed a few hundred amperes.

An application of the latter reasoning is this: if lightning strikes a transmission line and raises it locally to a high voltage, this voltage is limited by the disruptive strength of the line insulation, to for instance  $e = 100,000$ . The maximum current, which then can run along the line as impulse, and must be taken care of by the station

lightning arrester, is given as  $i_0 = e \sqrt{\frac{C}{L}}$ , and is not very formidable.

Thus in general, the effects of discharging a high voltage are far less dangerous than the effects of opening a large current.

We could carry this investigation still farther. We could see,

for instance, what amount of energy we could get from the line, etc., but I think these instances will be sufficient to illustrate what I meant by saying, that the law of conservation of energy is a most convenient and most useful tool in engineering calculations in eliminating cumbersome and inconvenient calculations by merely equating the energy which disappears at one point, with the energy which appears at some other point. We do not care how the transformation occurs, what the mathematical equations are. We know we have one form of energy, so we must get another form of energy, and the law of conservation establishes relations between the starting point and the end, without obliging us to go through the intermediate relations, which usually are more complex.

## DISCUSSION.

*Chairman B. J. Arnold:* I think that we will all concede, after hearing Dr. Steinmetz's address, that if any one can experiment with mathematics he can. I am sure we are all greatly indebted to Dr. Steinmetz for giving us this discourse this evening, and with your permission I shall extend to him a vote of thanks on behalf of the audience for being with us tonight. Dr. Steinmetz states that if there are any questions any one desires to ask he will be very glad to answer them.

*Mr. James H. Griffin:* Mr. Chairman, I would like to ask the doctor a question, if I may be permitted.

*Chairman Arnold:* Certainly.

*Mr. Griffin:* It is an old one, but I have never heard a satisfactory explanation of it.

We will take a coiled spring and place it under high tension by compressing the elements of the coil. Then while in that state we put it into sulphuric acid or some other acid, which dissolves the metal. My question goes to the point, as to what becomes of the energy which was stored in that spring.

*Dr. Steinmetz:* That question can be answered. It means that the heat produced by the chemical action in a coiled spring, when dissolved, is greater by the amount of energy stored in it than if the spring were not under pressure. The amount of energy which is stored in compressing the spring in heat measure is so insignificant compared with the energy of solution that you can not measure the difference calorimetrically, but you can prove that the compressed spring produces a greater heat in dissolving than the uncompressed spring, in an indirect manner. The measure of the chemical energy is the electrical potential difference. If you dissolve iron in an acid and the iron is under strain, partly compressed, partly not, you find an unequal corrosion due to local current between the different parts of the iron. If there is a local current it means that the different parts of iron have different potential differences against

the electrolyte, that is, different chemical affinities, and the part under strain is dissolved first, showing a greater potential difference and thus a greater heat produced in its solution. Thus, if only a part of the spring were compressed, the other part not, the compressed part would dissolve first in the sulphuric acid by the local current circulating between the two, showing that its solution gives more energy than that of the uncompressed part.

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### THE OCTAVE CHANUTE MEDALS.

Attention is called to the Octave Chanut medals, which are given yearly for the best paper in Civil Engineering, Mechanical Engineering, and Electrical Engineering. When Mr. Chanut was President in 1901 he created a fund to provide three bronze medals, to be awarded each year to the writers—members of the Society—who had presented the best paper on a subject in each of the three divisions of engineering. His object was to create greater interest in the Society and its proceedings, and to induce the membership to write worthy papers for presentation at the meetings. Each year a committee is appointed by the President and the Board of Direction, who pass judgment on the respective merits of the papers presented to the Society by members thereof during the preceding year. This committee finally reports to the Board of Direction its recommendation as to which of the papers it considers most worthy of receiving the prize of the Chanut medal. The bronze medals are then made and engraved, and a suitable Certificate of Award is engrossed and signed by the President and Secretary and by the Committee of Awards. The medals and certificates are delivered to the recipients and announcement is made to the Society through the Journal and at the Annual Meeting of the names of those who had been so honored by the Society. These awards have been made for each year since, and including, 1901. It is the desire of the administration of the Society that the awarding of these prizes for meritorious papers be well known to our membership, that they may be induced to prepare and present to the Society papers on engineering subjects worthy of the Octave Chanut medals.

# PROCEEDINGS OF THE SOCIETY.

## MINUTES OF THE MEETINGS.

*Extra Meeting, January 5, 1910.*

An extra meeting of the Society (No. 683) being the third meeting of the Bridge and Structural Section, was held Wednesday evening, January 5, 1910.

The meeting was called to order at 8:15 p. m. by Mr. T. L. Condron, chairman of the section, with about eighty-five members and guests present. The minutes of the last meeting, held December 8, 1909, were read and approved.

As this was the annual meeting, those put in nomination for the executive committee at the preceding meeting were to be voted on. The chairman appointed Messrs. Artingstall, Lawry, and Sanderson as tellers to canvass the ballots.

While this was in progress, Mr. W. C. Armstrong, vice-chairman of the Section, addressed the meeting on "Some Special Features of Steel Construction in connection with the New Northwestern Terminal." Stereopticon views were exhibited to illustrate the address. Discussion followed from the chairman, and Messrs. Gerber, Cartledge, Trumbull, Finley, Smetters, Dart, and Stern.

At the close of the meeting the secretary read the report of the judges of election, as follows:

	Votes.
For chairman, T. L. Condron.....	41
For vice-president, W. C. Armstrong.....	41
For members of the Executive Committee—	
Andrews Allen .....	36
C. R. Dart .....	31
F. E. Davidson.....	23
E. N. Layfield.....	18
S. T. Smetters.....	15

The chairman then announced that Messrs. T. L. Condron, W. C. Armstrong, Andrews Allen, C. R. Dart, and F. E. Davidson would constitute the Executive Committee of the Bridge and Structural Section for the year 1910.

The meeting adjourned at 10:15 p. m.

*Annual Meeting, January 12, 1910.*

The annual meeting (No. 684) and dinner of the society was held in the new building of the University Club of Chicago, Wednesday evening, January 12th, 1910, convening about 7 p. m. with about 165 members and guests in attendance.

There was no formal business before the society, but after the dinner President Allen addressed the meeting with a statement as to what had been done during the past year, showing the growth in membership, the income and expenditures for the year, the net gain, etc. He then introduced Mr. J. W. Alvord, the president-elect, and handed him the gavel. President Alvord acknowledged the introduction, and his election to the presidency in a happy manner. He then presented to the assembly Mr. Bernard E. Sunny, president of the Chicago Telephone Company, who addressed the meeting on "The Engineering of Chicago."

This able paper was followed by addresses from Hon. Bernard W. Snow, Hon. Milton J. Foreman, Mr. L. C. Fritch, Past-President Bion J. Arnold, and Mr. L. P. Morehouse, the first secretary of the society.

February, 1910

The meeting adjourned about 11 p. m., after a very enjoyable and satisfactory evening.

*Extra Meeting, January 19, 1910.*

An extra meeting of the society (No. 685) was held Wednesday evening, January 19th, 1910.

The meeting was called to order at 8:15 p. m. with President Alvord presiding, and about seventy-five members and guests in attendance. As there was no business before the society, Mr. William R. Wiley of Hazleton, Pa., was introduced, who presented his paper on Centrifugal Pumps. Discussion followed from Prof. A. N. Talbot (by letter), and Messrs. Babcock, C. W. Naylor and C. B. Stewart. The latter (of Madison, Wis.,) had a number of lantern slides to illustrate the results of investigations made at the University of Wisconsin, abstracted and condensed from Bulletin No. 318, issued by the University.

The meeting adjourned at 10:30 p. m.

*Joint Meeting of the Electrical Section W. S. E. and the Chicago Section A. I. E. E., January 26, 1910.*

An extra meeting of the society (No. 686) being a meeting of the Electrical Section (No. 47), held jointly with the Chicago Section of The American Institute of Electrical Engineers, was held in the Society rooms Wednesday evening, January 26th, 1910.

The meeting was called to order about 8:15 p. m., with Mr. W. B. Jackson, M. W. S. E., in the chair, and about ninety-five members and guests in attendance.

The minutes of the preceding joint meeting held December 22d, 1909, were read and approved.

The annual election of the executive committee was held, resulting in the election of Mr. George H. Lukes chairman, Mr. Garrett T. Seely as vice-chairman, and Prof. P. B. Woodworth as member to serve three years. Messrs. W. L. Abbott and E. N. Lake are also on the committee to serve two years and one year respectively.

The changes in the rules of the Electrical Section which had been presented at the preceding meeting, were voted on and approved.

The chairman then asked Mr. J. G. Wray, M. W. S. E., to preside, who introduced Mr. W. Lee Campbell, general superintendent of the Automatic Telephone Company, who addressed the meeting on the subject of "Recent Developments in the Automatic Telephone." The address was illustrated by apparatus and by a number of stereopticon views to show different forms and parts of the automatic telephone. A recess was taken to inspect the apparatus, consisting of an exchange switchboard and a number of instruments set up about the room so that they could be used and tested.

The meeting was then recalled to order and discussion followed from Messrs. Charles A. Winston, A. M. Haubrich, F. F. Fowle, T. E. Myer, N. J. Johnson, A. M. Belfield, A. Bement, and further explanation and replies to questions were made by Mr. Campbell.

As Mr. Wray had to leave early, he asked Mr. Lukes, the newly-elected chairman, to preside for the rest of the evening.

The meeting adjourned about 10:45 p. m.

*Regular Meeting, February 2, 1910.*

A regular meeting (No. 687) of the society was held Wednesday evening, February 2, 1910.

The meeting was called to order at 8:15 p. m. with Vice-President Chamberlain in the chair and about fifty members and guests present.

Minutes of the meetings of December 1, December 15, 1909, January 12, and January 19, 1910, were read and approved.

The secretary reported from the board of direction that the following had applied for membership:

L. D. Gayton, Milwaukee, Wis.....	Active
F. N. Holmquist, Phoenix, Ariz.....	Junior
John E. Lowther, Milwaukee, Wis.....	Active
Edward L. Jones, Chicago.....	Transfer, Active
Bernard E. Sunny, Chicago.....	Active
Philip G. Connell, Chicago.....	Junior
Jesse L. Haugh, Clyman, Wis.....	Junior
Joseph L. Hiller, Philadelphia, Pa.....	Active
Charles B. Nolte, Chicago.....	Junior
Harrison L. Garner, Madison, Wis.....	Junior
L. C. Fritch, Chicago.....	Active
Thomas Judson Wright, Jr., Winston, N. C.....	Junior
H. W. Snell, Chicago.....	Junior

And that the following has been elected into membership:

Joe D. Wood, Nyssa, Ore.....	Junior
Ralph H. Rice, Chicago.....	Active
Jesse B. Wright, Tucson, Ariz.....	Active
G. M. A. Ilg, Chicago.....	Junior
F. R. Mackendrick, Chicago.....	Junior
Porter R. West, Chicago.....	Junior
Edward J. Fucik, Chicago.....	Transfer, Active
Charles W. Brown, Jacksonville, Ill.....	Active
H. M. Wheeler, Chicago.....	Transfer, Active
Edgar D. Otto, Downers Grove, Ill.....	Junior
John A. Sauerman, Chicago.....	Junior
James S. Stone, Morgan Park, Ill.....	Active
Carl Scholz, Chicago.....	Active
W. R. Renwick, Cheboygan, Mich.....	Junior
John C. Penn, Chicago.....	Transfer, Active
John M. Wilson, Belle Fourche, S. D.....	Active
W. F. Kleene, Chicago.....	Junior
F. N. Holmquist, Phoenix, Ariz.....	Junior
John E. Lowther, Milwaukee, Wis.....	Active

The secretary then presented an abstract of the paper by Mr. Ralph Budd, M. W. S. E., on "The Panama Railroad and Its Relation to the Panama Canal." Written discussion followed from Messrs. J. F. Wallace, H. J. Slifer, and F. C. Harper.

It was a cause of regret that the author nor these gentlemen could not have been present to add to the discussion of this subject.

The meeting adjourned about 9:20 p. m.

#### *Extra Meeting, February 9, 1910.*

An extra meeting of the society (No. 688), being the fourth meeting of the Bridge and Structural Section, was held Wednesday evening, February 9, 1910.

The meeting was called to order by the chairman, Mr. T. L. Condon, at 8:15 p. m., with over 100 members and guests present.

The subject for the evening was "Reinforced Concrete Bridges" for the track elevation of the Chicago, Burlington & Quincy Railroad, as presented by Mr. C. E. Tebbitts; of the Chicago, Milwaukee & St. Paul Railway, as presented by Mr. E. O. Greifenhagen; and of the Illinois Central Railroad, as presented by Mr. F. L. Thompson. These papers were illustrated by a number of stereopticon views.

Discussion followed from Messrs. M. B. Wells, R. J. Middleton, ——— Hudson, W. H. Finley, F. G. Vent, C. K. Mohler, E. McCullough, H. S. Baker, I. F. Stern, and ——— Dwyer.

The meeting adjourned about 10:30 p. m.

February, 1910

*Extra Meeting, February 16, 1910.*

An extra meeting of the society (No. 689) was held Wednesday evening, February 16, 1910. The meeting was called to order at 8:15 p. m. with President Alvord in the chair and about fifty members and guests in attendance.

There was no business to be considered by the society, so Mr. A. Bement, M. W. S. E., was introduced, who presented the "Report on the Chicago Harbor Problem" as prepared by his committee.

The secretary read communications from Messrs. Richard Price Morgan and Isham Randolph, on the subject.

Discussion followed from Col. C. McD. Townsend, of Detroit, J. W. Mabbs, H. B. Ford, R. J. Mershon, George E. Hlooker, Andrews Allen, ——— Marsh, C. W. Naylor, and L. E. Cooley.

The meeting adjourned about 10:15 p. m.

*Joint Meeting of the Electrical Section, W. S. E., and the Chicago Section, A. I. E. E., February 23, 1910.*

An extra meeting of the society (No. 690), being the forty-eighth meeting of the Electrical Section, W. S. E., held jointly with the Chicago Section of the American Institute of Electrical Engineers, was held in the Society rooms, Wednesday evening, February 23, 1910.

The meeting was called to order about 8:25 p. m. with Prof. P. B. Woodworth in the chair and about ninety members and guests present. The minutes of the previous joint meeting of January 26 were read and approved.

The chairman introduced Mr. Edward N. Lake, who presented his paper on "Some Suggested Improvements in Underground Conduit Construction for Large Transmission Systems." The paper was illustrated by a number of stereopticon views.

Discussion followed from the chairman, and Messrs. D. W. Roper, Wm. B. Jackson, F. W. Baird, C. C. Darling, H. B. Gear and G. B. Springer, with a closure from Mr. Lake.

The chairman announced that the next joint meeting would be held four weeks hence, Wednesday, March 23.

The meeting adjourned about 10:10 p. m.

*Special Extra Meeting, February 24, 1910.*

A special extra meeting of the society (No. 691) was held in Fullerton Hall, Art Institute, Thursday evening, February 24, 1910. Mr. A. Bement, second vice-president, introduced the speaker, Mr. William V. Alford, C. E., of Garrettsville, Ohio, who gave an interesting and instructive address pertaining particularly to travels in Peru and Ecuador. The talk was illustrated by a considerable number of beautiful stereopticon views of the scenery, the people, and incidents of travel.

There were about 300 in attendance, a large proportion being ladies. The meeting adjourned about 10:15 p. m.

J. H. WARDER, Secretary.

## ANNUAL REPORTS.

### REPORT FROM THE JUDGES OF THE ELECTION.

January 7, 1910.

To the Western Society of Engineers.

Gentlemen:—The undersigned judges of election, having canvassed the ballots cast for officers of the Western Society of Engineers for the year 1910, have the honor to report as follows:

Total number of ballots cast.....	404
Number of ballots rejected as irregular.....	39
Number rejected as not qualified to vote on account of non-payment of dues .....	2— 41
 Total number of ballots counted.....	 363
Number of votes cast for President—	
J. W. Alvord.....	226
P. Junkersfeld .....	134
Number of votes cast for First Vice-President—	
O. P. Chamberlain.....	342
Number of votes cast for Second Vice-President—	
A. Bement .....	336
Number of votes cast for Third Vice-President—	
W. K. Hatt.....	217
A. Marston .....	136
Number of votes cast for Treasurer—	
A. Reichmann .....	337
Number of votes cast for Trustee for three years—	
W. W. Curtis.....	143
E. McCullough .....	104
M. K. Trumbull .....	101

Respectfully submitted,

(Signed)

JOHN M. SWEENEY.

G. F. DODGE.

F. F. SINKS.

### SECRETARY'S REPORT.

CHICAGO, January 12, 1910.

To the Board of Direction, Western Society of Engineers.

Gentlemen: Of the affairs of the Western Society of Engineers for the year 1909, I have the honor to report as follows:

Total membership in the society, December 31, 1908.....	993
Total number of applications received in 1909, 202, of which 162 were elected, 14 being transfers. To this number should be added 12 whose applications were received in 1908, but who were elected in 1909, making 174 elected in 1909 (including 14 transfers).	
Total number of new members elected in 1909 (not including transfers)..	160
	1,153
Losses through resignations, deaths, and dropped.....	68

Total membership December 31, 1909.....	1,085
Net gain in membership during the year.....	92

February, 1910

Since the last annual meeting, Mr. Grenville M. Dodge, of Council Bluffs, Iowa, was elected an Honorary member.

The classification of the membership December 31, 1909, was as follows:

Honorary members—

Resident .....	2
Non-resident .....	1

Active members—

Resident .....	493
Non-resident .....	359

Associate members—

Resident .....	58
Non-resident .....	9

Junior members—

Resident .....	119
Non-resident .....	44—1,085

Eight deaths occurred during the year, as follows:

George Adgate, January 23.  
 Henry F. Baldwin, June 17.  
 Carl W. Birch-Nord, September 15.  
 A. J. Caldwell, May 10.  
 Arthur B. Crozier, November 6.  
 Wm. E. Reynolds, February 24.  
 W. E. H. St. Lawrence, July 3.  
 J. W. Schaub, March 30.

During the year thirty-five meetings were held, as follows:

1 annual meeting.  
 9 regular society meetings.  
 10 extra society meetings.  
 3 electrical section meetings and  
 6 joint meetings, Electrical Section and Amer. Inst. E. E.  
 2 Bridge and Structural Section meetings.  
 4 social meetings.

The list is as follows:

*Tuesday, January 5, 1909:*

The thirty-ninth annual meeting (No. 648 of the Society) was held in the club rooms of the Chicago Athletic Association, followed by a dinner and addresses from Retiring President C. F. Loweth, President-elect Andrews Allen, Messrs. Onward Bates, James Hough-teling, Frank Trumbull and Grenville M. Dodge.

*Friday January 15:*

Regular and Annual meeting of the Electrical Section (No. 38) (being No. 649 of the Society), Prof. C. F. Burgess, of the University of Wisconsin, presented his paper on "*Corrosion in Steam Boilers as an Electro-Chemical Phenomena.*"

*Wednesday, January 20:*

Extra meeting (No. 650). Mr. James C. Davis, of the American Steel Foundries Co., presented his paper on "*Steel Castings.*"

*Wednesday, February 3:*

Regular Meeting (No. 651). Mr. H. E. Horton M. W. S. E., presented his paper on "*Water Storage in Elevated Tanks and Stand Pipes.*"

*Friday, February 5:*

Regular Meeting (No. 39) of Electrical Section (No. 652 of Society). Prof. Jagadis Chunder Bose, of the Presidency College, Calcutta, addressed the Section on "*Polarization of Electric Waves.*"

*Wednesday, February 17:*

Extra Meeting (No. 653). Mr. W. S. Potter, of the Manganese Steel Rail Co., Paterson, N. J., addressed the Society on "*Manganese Steel.*"

*Thursday, February 25:*

Extra Meeting (No. 654). Ladies' Night. Mr. Onward Bates gave an illustrated talk on his recent trip to the Orient.

*Tuesday, March 2:*

Regular Meeting of Electrical Section (No. 40) (being No. 655 of the Society). Messrs. C. A. S. Howlett, E. W. Lloyd and J. M. S. Waring presented papers on the "*Relation of Load Factor to Power Costs.*"

*Wednesday, March 3:*

Regular Meeting (No. 656). Mr. J. H. Prior presented his paper on "*Derrick Cars in Bridge Erection, with Some Tests of Pulley Blocks.*"

*Friday, March 19:*

Joint Meeting of the Electrical Section (No. 41) and Chicago Branch A. I. E. E. (being No. 657 of the Society). Prof. E. E. Creighton, of the General Electric Co., gave a demonstration of lightning phenomena.

*Wednesday, March 24:*

Extra Meeting (No. 658). Reminiscence Meeting.

*Wednesday, April 7:*

Regular Meeting (No. 659). Mr. A. Bement presented his paper on "*The Illinois Coal Fields.*"

*Friday, April 16:*

Joint Meeting of the Electrical Section (No. 42) and the Chicago Branch A. I. E. E. (being No. 660 of the Society). Mr. B. R. Shover, of Gary, Ind., addressed the meeting on "*The Electrical Equipment of the Gary Steel Plant.*"

*Wednesday, April 21:*

Extra Meeting (No. 661). Mr. Robert S. Perry, of Philadelphia, presented his paper on "*Protective Coatings for Structural Material.*"

*Wednesday, May 5:*

Regular Meeting (No. 662). Prof. L. P. Breckenridge gave an illustrated address on "*The Engineering Experiment Station and Its Relation to Illinois Industries.*"

*Wednesday, May 19:*

Extra Meeting (No. 663). Maj. W. V. Judson, of U. S. Engineers, presented his paper on "*Reinforced Concrete Caissons for Breakwaters, Piers and Abutments.*"

*Thursday, May 27:*

Extra Meeting (No. 664). Ladies' Night. Mr. Isham Randolph gave an illustrated talk on his trip to Panama in January, 1909.

February, 1910

*Friday, May 28:*

Joint Meeting of the Electrical Section (No. 43) (No. 665 of Society) and Chicago Branch A. I. E. E. Members of the Board of Supervising Engineers (Messrs. Arnold, Fleming and Weston) spoke informally on certain phases in the development of the street railway systems of Chicago.

*Wednesday, June 2:*

Regular Meeting (No. 666). Mr. J. F. Jackson, M. W. S. E., addressed the Society on "*Some Observations on the Stability of Dams.*"

*Wednesday, June 16:*

Extra Meeting (No. 667). Mr. George Weston, M. W. S. E., presented his paper on "*Reconstruction of Street Car Tracks in Chicago.*"

*Wednesday, September 1:*

Regular Meeting (No. 668). Mr. Willis McKee, of Elyria, Ohio, addressed the Society on "*The Rolling of Special Sections of Iron and Steel.*"

*Wednesday, September 15:*

Extra Meeting (No. 669). Mr. John M. Ewen presented his paper on "*The Chicago Harbor.*"

*Wednesday, October 6:*

Regular Meeting (No. 670). Mr. C. T. Barnum, of the Forest Service, U. S. Dept. of Agriculture, presented his paper on "*Wood Preservation from an Engineering Point of View.*"

*Wednesday, October 20:*

Extra Meeting (No. 671). Mr. Octave Chanute gave an illustrated address on "*Recent Progress in Aviation.*"

*Friday, October 22:*

Joint Meeting of the Electrical Section (No. 44) and the Chicago Branch A. I. E. E. (being No. 672 of the Society). Mr. W. L. Abbott, of the Commonwealth Edison Co., addressed the meeting on "*Central Station Economies.*"

*Wednesday, November 3:*

Regular Meeting (No. 673). Mr. L. W. Page, office of Public Roads, U. S. Dept. of Agriculture, presented his paper on "*Macadam Roads and Their Preservation.*"

*Wednesday, November 10:*

Extra Meeting (No. 674). First meeting (for organization) of the Bridge and Structural Section.

*Tuesday, November 16:*

Joint Meeting of the Electrical Section (No. 45) and the Chicago Branch A. I. E. E. (being No. 675 of the Society). Dr. Charles P. Steinmetz delivered an address in Fullerton Hall, Art Institute, on "*The Law of the Conservation of Energy.*"

*Wednesday, November 17:*

Extra Meeting (No. 676). Mr. Paul P. Bird addressed the Society on "*Chicago's Smoke Problem.*"

*Friday, November 26:*

Extra Meeting (No. 677). Further discussion of Mr. Bird's paper on "*Chicago's Smoke Problem.*"

*Wednesday, December 1:*

Regular Meeting (No. 678). Mr. George S. Rice, M. W. S. E., addressed the Society on "*Mine Accident Investigations of the U. S. Geological Survey.*"

*Wednesday, December 8:*

Extra Meeting (No. 679). Bridge and Structural Section (second meeting). Messrs. Dart and Smetters, of the Sanitary District of Chicago, described certain features of the "*Eight-Track Bascule Bridge, Campbell Avenue.*"

*Friday, December 10:*

Extra Meeting (No. 680). Ladies' Night. Mr. C. E. Schauffler, M. W. S. E., gave several numbers on the violin, with piano accompaniment, and Mrs. Andrews Allen read Tennyson's "*Guinevere*" to a musical setting.

*Wednesday, December 15:*

Extra Meeting (No. 681). Mr. T. L. Condron, M. W. S. E., addressed the Society on "*A Unique Type of Reinforced Concrete Building Construction.*"

*Wednesday, December 22:*

Joint Meeting of the Electrical Section (No. 46) and the Chicago Branch A. I. E. E. (being No. 682 of the Society). Mr. R. H. Rice addressed the meeting on "*Low Tension Feeder Systems for Street Railways.*"

The usual summer cleaning of the furniture and rooms, fresh calcimining of the walls, etc., was done during the summer vacation. Some additional bookstacks were bought and rearranged in the library; also some changes and improvements were made in the electric lighting of the rooms. The increased attendance in the reading room and constantly growing use of the library is gratifying.

Very respectfully submitted,  
J. H. WARDER,  
Secretary.

LIBRARIAN'S REPORT.

January 12, 1910.

*To the Board of Direction, Western Society of Engineers, Chicago.*

GENTLEMEN: The librarian begs to submit the following as his report on the library of the Society for the year 1909:

Number of books accessioned up to December 31, 1909..... 7,458  
Number of books accessioned up to December 31, 1908..... 6,957

Additions to the library during 1909..... 501

These may be classified as follows:

Number of volumes bound by the Society..... 115  
Number of bound books (gifts and exchanges)..... 275  
Number of volumes bought..... 80  
Number of pamphlets accessioned..... 31

Total charge against library for 1909.....\$527.08

February, 1910

Classified as follows:

Services .....	\$200.73
Books purchased .....	208.23
Binding .....	108.57
Sundries .....	9.55
Total .....	\$527.08
Furniture and fixtures.....	299.10
Total .....	\$826.18

Respectfully submitted,  
J. H. WARDER,  
Librarian.

## TREASURER'S REPORT FOR THE YEAR 1909.

January 2, 1910.

*To the Board of Direction, Western Society of Engineers, Chicago, Ill.*

GENTLEMEN: I respectfully submit herewith a statement of the treasurer's account for the year ending December 31, 1909, as follows:

## CASH STATEMENT.

January 1, 1909, cash in bank subject to check.....	\$ 1,188.77
January 1, 1909, cash on hand, not deposited.....	255.75

## RECEIPTS.

Dues .....	\$ 8,475.72
Entrance fees .....	1,393.00
Subscriptions to Journal.....	357.23
Advertising .....	2,620.80
Sales Journal .....	102.85
Interest .....	526.29
Journal account .....	14.50
Library account .....	23.75
House expense .....	337.75
Stationery, postage and exchange.....	42.89
General printing .....	178.88
Chanute medal fund.....	25.00
Investments .....	1,800.00
Bound Journal .....	5.00
Suspense account .....	5.00
	<hr/>
	15,908.66
	<hr/>
	\$17,353.18

## EXPENDITURES.

Advertising .....	\$ 24.00
Journal account .....	4,898.54
Library account .....	550.83
House expense .....	4,623.29
Stationery, postage and exchange.....	857.41
General printing .....	949.60
Services .....	1,800.00
Furniture and fixtures.....	299.10
Chanute medal fund.....	59.00
Colonial Trust & Savings Bank.....	1,600.00
	<hr/>
	\$15,661.77
December 31, 1909, cash in bank subject to check.....	1,691.41
	<hr/>
	\$17,353.18

Vol. XV, No. 1

## SUMMARY.

## Statement January 1, 1909.

To credit of Western Society of Engineers.....	\$ 6,853.32
Chanute medal fund.....	1,199.00
Arnold fund .....	1,000.00

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\$ 9,052.32

Investments .....	\$ 9,207.80
Cash .....	1,444.52

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\$10,652.32

Col. Trust & Savings Bank loan.....	1,600.00
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\$ 9,052.32

## Statement January 1, 1910.

To credit of Western Society of Engineers.....	\$ 6,875.21
Chanute medal fund.....	1,224.00
Arnold fund .....	1,000.00

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\$ 9,099.21

Investments .....	\$ 7,407.80
Cash .....	1,691.41

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\$ 9,099.21

Respectfully yours,

A. REICHMANN,  
Treasurer.

## BOOK REVIEWS.

**THE STEAM ENGINE.** By Prof. Chas. H. Benjamin, Dean of the Schools of Engineering, Purdue University. The Technical Press. Brattleboro, Vt. Cloth; 6 by 9 ins.; pp. 316; illustrated.

Those who are familiar with Prof. Benjamin's previous writings will find it sufficient comment on this book to know that it is worthy of the author. To those who have not had the pleasure of reading his books, it will be worth knowing that Prof. Benjamin is chiefly noteworthy for doing things that are worth while, and that in engineering what appeals to him is that which will be useful to his fellow men. The present work is intended for students and is directed particularly to their needs, but several of the chapters are worthy of place in a reference library because of their new material or new method of treatment.

In the earlier part of the book the noteworthy feature is the condensed, yet clear treatment, of the thermodynamics of air and steam, particularly those portions which deal with the temperature entropy diagram and its uses. The explanation of this comparatively modern method of analyzing heat action makes it a useful working tool of the engineer instead of, as has been the case in many works, a mathematical curiosity. The details of the engine and of engine action are explained so that those coming to the subject for the first time will be able to grasp them readily, including chapters on valve and link motions, indicators and diagrams, governors, flywheels, condensers, and heaters. A chapter on the compound engine discusses not only the reason why of this type of prime mover, but shows the method of determining the cylinder dimensions of such engines, and discusses the reason that the compound engine is less efficient on variable load than where the load is reasonably steady. The action of the engine under different methods of load variation is carefully considered.

In the chapter on governors the ordinary forms of pendulum and shaft governor are treated, and an original method for graphic analysis, showing the effect of change of speed and of friction in the shaft governor, is given. In a chapter on the action of steam and cylinder an interesting portion is that devoted to superheated steam, in which is embodied a diagram giving the latest researches as to the specific heat of this most elusive substance.

On piping and flow of steam a rational formula is derived which is shown to correspond closely with the results of experiment, and a table of flow of steam through pipes at different initial pressures is given which will be found convenient in design. Also the results of different sets of experiments to determine the loss by condensation in uncovered pipes is interestingly discussed. Steam engine performance is treated rather from the standpoint of actual results from tests than from theory, and in this chapter considerable new material has been incorporated. The comparison of steam economy for different classes of engines is specially interesting and also a diagram showing variation in initial pressure and point of cutoff for best economy. Design of engines is treated rather briefly, but formulas are given for the dimensions of the main parts. The chapter on specifications and costs has a set of specifications made up from the purchaser's standpoint and one made up from the engine builder's standpoint. The comparison of these two is interesting and gives the points to be looked after in making such specifications. On the matter of cost the results of two investigations made by the author are given, and it is shown that the average cost varies almost in a straight line relation with the power. There is a certain initial charge, and above this added power means added price. This is, however, only for the average line, as the actual prices submitted

for different sizes of engines vary widely from the average line. At the end of the book are given tables of the properties of saturated steam, weight of water, properties of anhydrous ammonia and hyperbolic logarithms, the ones which are most frequently used in the study of thermodynamics and problems on the steam engine.

The author has certainly accomplished his purpose, which is to explain the elementary principles of heat engines so that they might be readily understood, and to show the application of these principles in the design, construction, and operation of modern reciprocating engines.

A. S. R.

#### MACHINE BUILDING FOR PROFIT AND THE HARTNESS FLAT TURRET LATHE.

By James Hartness. Jones & Lamson Machine Co., Springfield, Vt. Cloth; 6 by 9 ins.; pp. 253; many illustrations.

This is an exquisitely gotten up book, with one colored picture and some 200 half-tones and line drawings.

The reviewer feels quite justified in calling it a book, as its value to the reader is far above the one of the ordinary trade literature, from which the author, by his general and rather impartial treatment of the subject, earnestly endeavored to get away, although the advertising purpose cannot be entirely denied. But in reading even the highest type of literature of our present time we have to bear in mind that the author, directly or indirectly, had a dollars-and-cents interest in view when writing his work, and so the unprejudiced reader who is in want of information has not much reason, if any, to judge the author harshly.

In the first section on "Economics" is given a sound analysis of the use and distribution of the dollar which is being put in a machine factory, and the profit which it may or may not bring, touching in a psychological way upon the factory and department management.

The advantages of specialization and concentration of energy in factory life, and also the dangers of branching out into too many lines, are treated very plausibly, and this chapter is, in the reviewer's opinion, the most valuable one in the book. It makes the latter a requisite in the library of the commercial engineer or manager.

Further on are given chapters on principles of lathe and turret lathe designs, observations and views on running machines, and various points of importance and adaptability; also extracts from "Evolution of the Machine Shop."

The second section is entirely devoted to the description and illustration of the Hartness flat turret lathe, made by the publishers; also to work done on same. A number of line drawings are given, showing the floor and drive plans, with dimensions. This section is of value to the prospective user, and his mechanic or superintendent particularly.

H. G.

A TEXT BOOK ON GRAPHIC STATICS. By Charles W. Malcolm, C. E., Asst. Prof. of Structural Engineering. University of Illinois. The Myron C. Clark Pub. Co., New York and Chicago. 1909. Cloth; 6 by 9 ins.; pp. 316. Price, \$3.00 net.

This book is divided into four parts. Part 1 treats of the general principles which govern graphic representation of forces; special chapters are devoted to concurrent and non-concurrent forces, moments, and moments of inertia. The chapter on center of gravity of areas is valuable, while portions of the article on graphic moments and also on moment of inertia of areas seem to carry the scientific research beyond the practical limit.

The remaining three parts relate to framed structures, being entitled Roof Trusses, Beams, and Bridges, respectively. Under roof trusses is presented the dead, snow, and wind loads and their reactions, both for fixed trusses and those free to move at one end. The methods of

determining stresses in roof trusses by both the algebraic and graphic moment and resolution are shown. An analysis of the principal kinds of roof trusses, and also the three-hinged arch and of the stresses in a post supporting a roof truss, is given.

Beams are divided into cantilever, simple, overhanging and restrained and bending moment, shear and deflection diagrams for fixed and moving loads, are discussed.

The part devoted to bridges has a chapter on the types of trusses; also one on loads, which gives, under dead loads, the approximate weight of highway and railway spans; under live load, the load per square foot for highway and uniform and wheel loads for railway bridges; and under wind loads the lineal foot or square foot load to assume. The stresses in several types of trusses are analyzed. A chapter is devoted to influence diagrams which indicate positions for maximum moments and shears. The author has here followed a large number of his predecessors, but the reviewer believes that a better method is to consider the influence points where it is desired to find the maximum moment, or between which it is desired to find the maximum shear; what reactions these points would receive in case they were points of supports, as these reactions have a fixed relation to the shear or moment, and the maximum shear or moment are shown by these reactions.

The book answers very well for a text-book, has plenty of illustrations, covers more ground than its title indicates, and does it in a thorough manner.

J. G.

CONCRETE BRIDGES AND CULVERTS. For Railroads and Highways. H. C. Tyrrell, C. E. Myron C. Clark Pub. Co., Chicago and New York. 1909. 4¾ by 6¾ in.; leather bound; 251 pages, including index. Price, \$3.00.

The author, as is to be expected, is an enthusiastic advocate of concrete, and his preference seems to be for plain concrete rather than with reinforcement. But the author does not go into the mathematical analysis of design, and the book is more of a description of work executed. There are introduced sundry tables of costs which are of value. "In the preparation of this manual the effort has therefore been made to as far as possible eliminate mathematical formulas and present the subject in the simplest possible manner. Only such material is given as is directly required in the design and construction of ordinary concrete or masonry arches." (Extract from preface.)

Part I treats of plain concrete arch bridges, amounts to 95 pages, and is a good summary of the subject.

Part II, of 74 pages, relates to Reinforced Concrete Arch Bridges.

Part III, of 4 pages, pertains to Highway Beam Bridges, and finally Part IV describes Concrete Culverts and Trestles.

Sundry tables through the text relate to Concrete Arch Bridges, Reinforced Concrete Arches, Highway Beam Bridges, Reinforced Concrete Culverts, etc. Some diagrams are also introduced to show costs of structures. There are also illustrations with dimensions of standard work, which can be used with advantage in many plans and thus save the time and cost of preparation of original designs. For some engineers, that part of the book containing the working drawings, particularly of culverts, etc., will be of value. But there is lacking a consideration of constructive problems, including the very important matter of forms. The construction of forms not properly designed may lead to such costs as to seriously diminish, if not wipe out, any profits on the contract. Nevertheless, the book contains much that is of merit and will fill a want with city engineers, county surveyors, and road commissioners.

The paper and type work are good and the leather binding and size make it available to carry in the field for reference.

W.

**ELECTRIC POWER CONDUCTORS.** By Wm. A. Del Mar, Assoc. Mem. A. I. E. E., Asst. Engr. Electrical Transmission Dept., New York Central Railroad. D. Van Nostrand Co., New York. Cloth; 5½ by 7½ ins.; pp. 339. Price \$2.00.

This book will undoubtedly be of great value to engineers who are concerned with the calculation of conductors for electrical transmission and distribution. The material has been collected from personal notes and published material that has been found accurate.

The different considerations to be taken into account when purchasing and selecting conductors are carefully described; tables, formulae, etc., are given, illustrating the different electrical and mechanical properties. A knowledge of the methods of manufacture of cables and insulation is necessary to the purchaser in order that specifications may be drawn up intelligently. This matter receives detailed attention from the author, who has devoted considerable space to the description of the manufacture of cable and to examples of cable specifications.

The simplest and most accurate formulae have been selected for the calculation of conductors. These formulae have been evolved from the fundamentals and are readily applied, requiring no complicated calculations. Tables and curves are given to supply many of the quantities required. These formulae cover the ordinary calculations of lighting installations, railway feeders, alternating current transmission, etc. The mechanical considerations met with when designing distribution systems are discussed from the standpoint of Kelvin's law.

Considerable space is devoted to the determination of the size of conductors for resisting mechanical stresses. Standard tests used for locating cable faults are described with reference to their particular application. The construction of transmission lines is discussed from the standpoint of present practices.

Considerable space is devoted to the depreciation and deterioration of cables. The author suggests many remedies to overcome deterioration due to electrolysis and other causes. The different types and methods of rail bonding and welding are compared and the advantages and disadvantages of the different types discussed. The latter portion of the book is partially devoted to the basic formulae used in the calculation of conductor sizes. For the benefit of those who desire to have a better understanding of the subject the development of the simplified formulae is explained.

The book covers a wide field in a brief and clear manner, as the matter presented is to the point and of an extremely practical character. There are many books on this subject of little value to engineers by reason of the complicated formulae and the absence of practical matter. This book, however, should be of great value because of its eminently practical character, based upon actual experience.

E. W. G.

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"30th Annual Report of Director of the U. S. Geological Survey." Pam.

Department of Agriculture—

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Bureau of Education—

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"Report for 1909." Cloth.

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### MISCELLANEOUS.

University of Wisconsin, Madison, Wis.—

"Bulletin 318." Pam.

"Investigation of Centrifugal Pumps." Part 2. C. B. Stewart.

Sheffield Scientific School, New Haven, Conn.—

Catalogue, 1909-10. Pam.

Lindon Bates, Jr., New York, N. Y.—

"Distribution in New York of the Catskill Water Supply." Bates. Pam.

"The Loss of Water in New York's Distribution System." Bates. Pam.

Sherman M. Turrill, Chicago—

"Elementary Course in Perspective." Turrill. Cloth.

R. R. Commissioners, State of Connecticut—

"57th Annual Report, 1909." Cloth.

E. E. R. Tratman, M. W. S. E., Chicago—

“Oscillations of Railway Rolling Stock.” Pam.

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J. W. Alvord, M. W. S. E., Chicago—

Notes on Going Value and Methods for Its Computation, of Water Works Valuation.” Alvord. Pam.

Scientific Publishing Co., Manchester, Eng.—

“Fowler’s Mechanical Engineers Pocket Book, 1910.” Leather.

“Fowler’s Electrical Engineers Pocket Book, 1910.” Leather.

American Gas Institute—

“Proceedings, 1909.” Cloth.

McGraw Publishing Co., New York, N. Y.—

“Electrical Directory (Railway Edition), January, 1910.” Leather.

Wood Preservers Association—

“Proceedings 2d, 3d and 5th Annual Meetings, 1906-7-9.” 3 Pams.

Gonzalo Ledon, Cuban Consul, Chicago—

“La Republic de Cuba.” Folio.

Public Service Commission, New York, N. Y.—

“Annual Report for Year Ending December 31, 1908.” 3 Cloth, 1 Pkg.

John Wiley & Sons, New York, N. Y.—

“Modern Framed Structures.” Johnson, Bryan & Turneaure. Cloth.

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## NOTICE

From the dues of each member, \$2.00 is set aside as a subscription to the JOURNAL.

February, 1910

# Journal of the Western Society of Engineers

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No. 2

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## RECENT PROGRESS IN AVIATION.

OCTAVE CHANUTE, HON. M. W. S. E.

*Presented October 20, 1909.*

*President Allen:* It is a remarkable coincidence that just twelve years ago this evening—October 20, 1897—Mr. Chanute gave his first paper before this society on the subject of aviation, the paper being entitled "Gliding Experiments." A few years later, in 1901 and again in 1903, Mr. Wilbur Wright appeared before the society at Mr. Chanute's invitation, and gave an account of the experiments then being made by himself and his brother Orville. The opportunity comes to very few men, I think, to appear before the same body twelve years after their predictions had been made, and be able to point to the fulfillment of those predictions, as can be done by Mr. Chanute tonight.

It is our privilege to listen to him now, at a time when aviation has become a matter of great public interest, and when he can point to the fulfillment of his own prophecies, and the launching of the aeroplane as a practical machine on the ideas that he enunciated in our rooms twelve years ago. Mr. Chanute is well known to us all and needs no introduction from me. We are proud to number him among our members as perhaps the foremost living authority on aviation today, in this country or in any other country.

*Mr. Octave Chanute, HON. M. W. S. E.:* I shall endeavor, with the aid of some lantern slides, to talk to you about what has lately been accomplished with flying machines. As your president has said, on the 20th of October, 1897, I had the honor of presenting to you an account of some gliding experiments that were carried on at Dune Park, near this city. Those experiments were made solely to study the question of equilibrium and to determine if it was reasonably safe to experiment. We had the good fortune to make about 2,000 flights (Mr. A. M. Herring, Mr. W. Avery and myself) without any accidents—not even a single sprained ankle. The only thing we had to deplore was the fact that my son, in making one flight, tore his trousers. An account of these experiments was published in the journal of this society for October, 1897, and subsequently an account was also published in the Aeronautical Annual, Boston, in 1897. That publication contained the statement that it was thought that these experiments were promising, and I gave

an invitation to other experimenters to improve upon our practice. That invitation remained unaccepted until March, 1900, when Wilbur Wright wrote to me, making inquiries as to the construction of the machine, materials to be used, the best place to experiment, etc. He said that he had notions of his own that he wanted to try, and knew of no better way of spending his vacation. All that information was gladly furnished. Mr. Wright wrote me an account, subsequently, of his experiments in 1900, which gave such encouraging results that each year thereafter the brothers carried on further experiments in North Carolina and at Dayton, Ohio.

On the 18th of September, 1901, Wilbur Wright read a paper before this society, in which he gave an account of what he had done up to that time.

Again, on the 24th of June, 1903, Mr. Wright read a second paper before this society, giving an account of his progress since 1901. Late in the year 1903 the Wrights applied a motor to their gliding machine, which by that time they had under perfect control, and they made their first flights on the 17th of December, 1903. (I might mention that I was present on each of the years during part of the experiments.) At that time Wilbur Wright expressed his intention of giving to this society the first technical paper on the subject which he furnished to any one. He said he had already promised to give a popular account in the *Century Magazine*, but that a technical paper, giving an account of the results and the laws which had been observed, would be reserved for this society.

In 1905 Mr. Wright told me it had dawned upon him that there was some money to be made by selling the invention to governments for war purposes, and that he would defer giving a technical paper to our society. He considered that his invention would be more valuable if, with the machine, he could give the secrets of construction and laws which have been observed. I do not know whether the paper has been written, but I hope you will get it some day.

Of the early flying experiments which had been made previous to that time I will mention but two.

Figure 1 represents the Maxim machine of 1894. Mr. Maxim built an enormous apparatus, weighing 8,000 lb. and spreading 4,000 feet of surface, moved by a steam engine of 360 H. P. That machine was run upon a track of 9 ft. gauge a good many times, and on one occasion it undertook a vagabond flight on its own account; its equilibrium was bad, however, and the steam was shut off; the machine alighted somewhat broken. Mr. Maxim saw clearly that it would be necessary to change the design and he has never rebuilt that machine.

Another view of the same machine is shown in Fig. 2. It had a large aeroplane at the top and two propelling screws 17

ft. 10 in. in diameter, which imparted a speed of 45 miles an hour running over the track, and it was held from rising by wooden rails of 35 ft. gauge which engaged outrigger wheels as soon as the machine left the sustaining track.

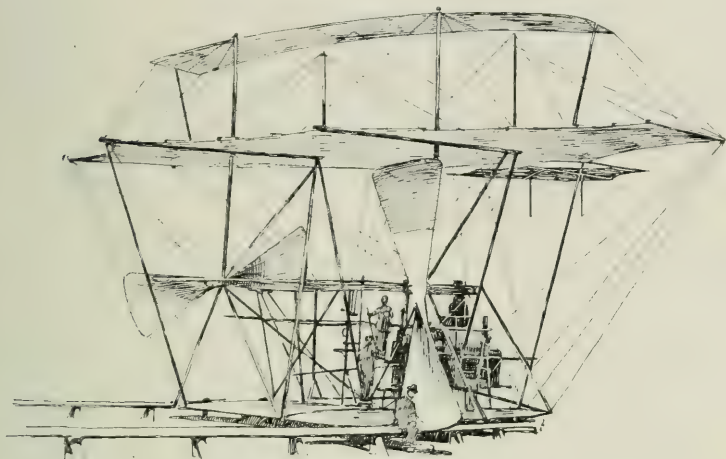


Fig. 1.—Maxim's Multiplane, 1894—Front View.

Weight, 8,000 pounds. Propelled by 363-horsepower steam engine. Span, 126 feet; area, 4,000 square feet; cost, \$200,000.

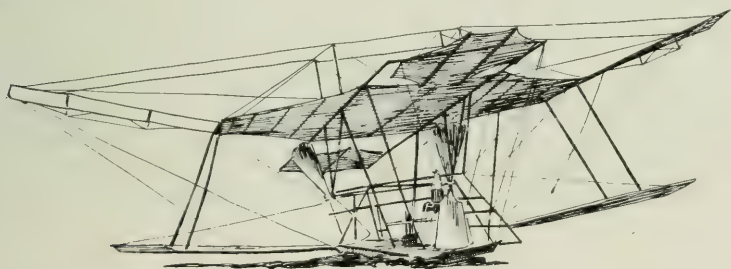


Fig. 2.—Maxim's Multiplane, 1894—Side View.

When run on rails at Baldwyn's Park, England, July 31, 1894, at 36 miles an hour, this machine lifted so much more than its weight that it broke a set of rails provided to hold it down and thus demolished itself.

Maxim is now said to be building another machine, which it is expected will be completed soon.

The next experiments were made in 1896 by Prof. Langley. After devoting some years to experimenting, he devised a working model which he started from a launching scow. The model machine flew perfectly on the 6th of May, 1896, in the presence of Alexander Graham Bell. This machine, shown in Fig. 3, flew

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about three-quarters of a mile, alighted safely in the Potomac River, and was ready to fly again.



Fig. 3.—Langley's 25-pound Tandem Monoplane, 1896.

Wings at dihedral angle. This model on May 6, 1896, flew for more than half a mile over the Potomac river, at a speed of about 20 miles an hour. Subsequently, on November 28, 1906, with a similar model weighing about 30 pounds, a three-quarter mile flight at about 30 miles an hour was achieved. The size of the heavier model was a little over 12 feet from tip to tip, with a length of about 16 feet.

On the 28th of November, with a similar model, Langley made another successful flight, and further launches were privately made subsequently.

He was then urged by the United States Government to build a full-sized machine, capable of carrying a man, and he spent three or more years in doing so. That man-carrying machine was completed in 1903, and on the 7th of October of that year the launch was attempted. The machine, however, caught a projecting pin of the launching rail and was cast down into the Potomac. The operator, Mr. Manly, was upset, carried down into the river, and came very near drowning. Another effort was made December 8th and the same mishap occurred. Part of the launching ways caught the machine, and it never entered upon flight. There is no doubt, however, that if the machine had been properly launched, it would have flown. The machine is still in existence and may be launched next year or perhaps later. It was broken when alighting, and in picking it up afterwards, but has been repaired. It is most unfortunate that further effort was not then made to launch that machine, and that Langley was so severely criticised in Congress and by the newspapers. He was grievously balked of deserved success, and he died of apoplexy two years afterward.

The next attempt to fly with a man-carrying machine was in North Carolina on the 17th of December, 1903, when the Wright brothers effected three successful flights, the first to alight safely in history. The longest flight covered 852 ft. and occupied 59 seconds, in the face of a 20-mile wind. The weather was so inclement that they then took the machine down and

abandoned experimenting for that year. There had been unfortunately some previous delays and breakages. When I went there in November to see the launching of the machine, it was postponed first by the twisting off of the shaft, and then by the breaking of the propeller, which required sending it back to Dayton in order to repair the work in the shop, but full success was attained at last. In 1904 they operated in a field about eight miles from Dayton, Ohio, and it took them most of that year to learn how to turn a corner. The machine was slightly broken a number of times, repaired, and finally, in October, 1905, they got their apparatus under perfect control, and succeeded in making a flight of 24 miles in 38 minutes. They made 105 flights in 1904 and 49 flights in 1905.

Figure 4 shows the system which they have adopted in order to avoid carrying too powerful and heavy a motor. The machine is placed on a single rail, weights are hoisted on a



Fig. 4.—Wright Machine on Starting Rail, with Starting Derrick in the Background.

derrick, and a rope is carried from the derrick with a return pulley to the machine. Upon the dropping of the weights the machine is given an impulse; this method being found to be preferable to the catapult which Mr. Langley had devised and which failed him on two occasions when trying to launch his machine.

In Fig. 5 is shown the machine at the inner end of the launching rail, just before it gets under motion. The launching rail is 60 ft. long, and with the aid of the falling weights the machine quickly acquires the necessary velocity for rising in the air.

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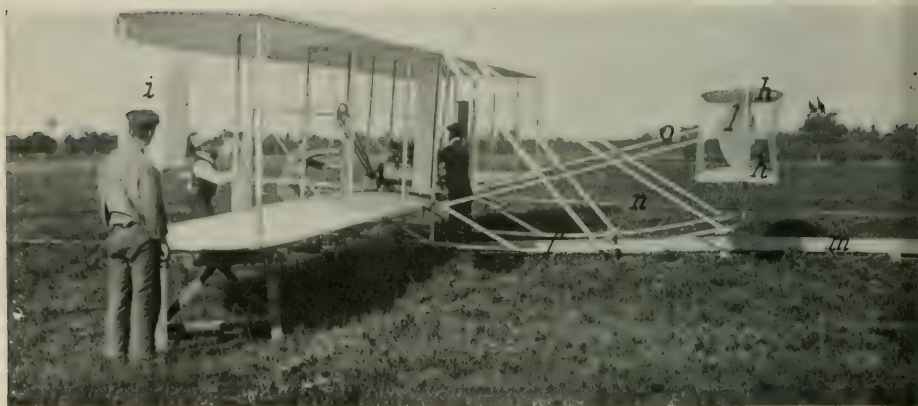


Fig. 5.—Wright Machine on Starting Rail.

The years 1906 and 1907 were spent by the Wright brothers in an effort to sell their machines to various governments. They had taken out patents in eight different countries, and they hoped to sell flying machines to war departments, together with the secrets, the tables of resistance, and all the elaborate calculations which they had made, but in each and every case the government wanted to be shown the apparatus before buying. The Wrights refused to exhibit the machine until such time as they had a contract contingent upon their performing certain feats—notably, to fly with two passengers and with enough fuel to carry it 125 miles; that it must attain a speed of at least 36 miles an hour, maintained over a distance of five miles, and must fly continuously for one hour.

None of the governments would thus contract with them. They were offered at one time \$120,000 by the French Government, but they refused. They were then offered \$200,000 if they would perform their feats 1,000 ft. in the air. To this they said that they had no doubt that they could get up 1,000 ft. but they had never done so and would not agree to the proposition.

In 1908 they changed completely their plan of operation and decided to show their machine with the risk of its being copied and getting themselves into litigation.

In Fig. 6 is shown the machine of the 1908 design, at Le Mans, where Wilbur Wright first exhibited it to the French, while a contract had been made in this country with the United States Government to furnish a similar machine. Fig. 7 represents a three-fourths front view of the machine. There is at the front a double-decked horizontal rudder. It will be noticed that these inventors have modified the make-up of a bird by putting the tail in front. Behind, are placed vertical rudders, but it is

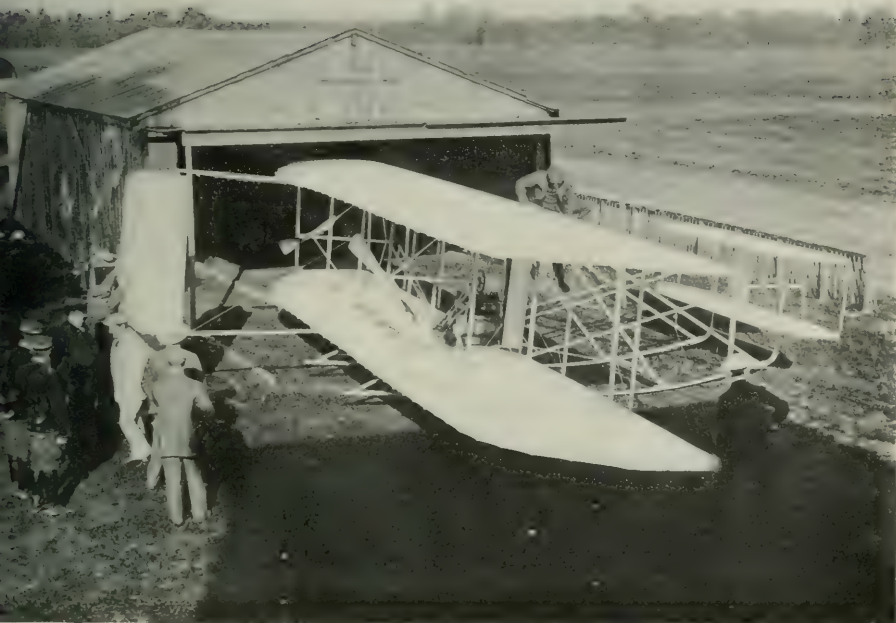


Fig. 6.—Side View of Wright Machine.

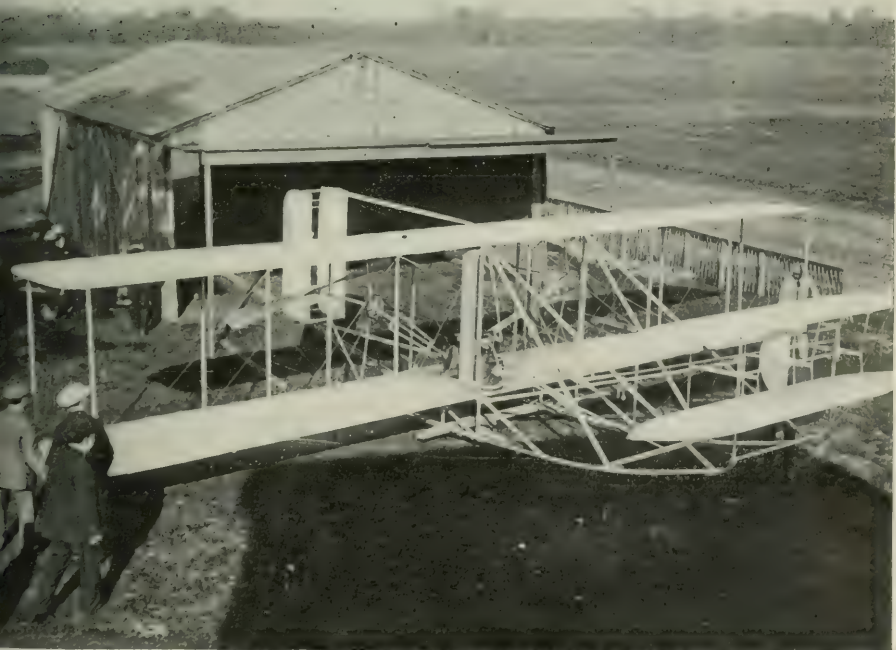


Fig. 7.—Three-Quarters View of Wright Machine.

the front rudder which elevates and gives horizontal direction to the machine. The rear rudder guides the machine to the right or left. Back of the main surfaces are the two screws revolving in opposite directions.

A side view of the same machine, taken at Le Mans, is shown in Fig. 5, previously mentioned. *i* designates the rear vertical rudder and *h* the horizontal rudder, operated by rods *o*, while *m* is the starting rail, *n* the rope, and *p* the skids or runners. The machine is equipped with a pair of skids for alighting, while the French people have equipped their machines with wheels. The wheels weigh more, catch more air, and are not as safe as the skids, but the skids require a rail and a starting falling weight in order to get the machine into the air, unless there is a brisk head-wind.

Figure 8 is from a remarkable photograph sent to me by Wilbur Wright, which was taken just at dusk.



Fig. 8.—Wilbur Wright Flying at Dusk.

Mr. Wright had extraordinarily good fortune in carrying on the experiments in France, his machine falling only once. One other accident occurred in the breaking of one of the sprocket chains in mid-air; but he then operated the machine as a glider and came down safely. The French people at first made all sorts of comments, criticisms, and caricatures of Wilbur Wright, and even published a number of amusing songs, but finally he triumphed, won their esteem and admiration, and they acknowledged that he was the master of all the aviators. Fig. 9 shows one of the flights at Le Mans. From Le Mans he went to Auvours in order to get better ground, and there made over 100 flights.



Fig. 9.—Wilbur Wright at Le Mans.

The more remarkable performances which he made I have undertaken to tabulate, but I will not inflict those statistics upon you this evening. Mr. Wright established great records, however. On the 18th of December, 1908, he flew 62 miles in 1 hour and 54 minutes, this being at that time the world's record, and he beat this directly afterward, on the 31st of December, by flying 77 miles in 2 hours, 20 minutes and 23 seconds, thus winning the Michelin prize and establishing a world record which was only beaten in the tournament at Rheims three weeks ago. In Rome he took up a great many passengers, and on one occasion he started without the use of starting weights, simply facing a wind of sufficient intensity and going up straight from the ground. Fig. 10 shows one of these flights.

On the 25th of September, after returning to America, and after he had been universally acclaimed in this country, and overwhelmed (modest man that he is) with public dinners, receptions, and medals, he encircled in flight the Statue of Liberty in New York harbor, and made a magnificent flight of 21 miles from Governor's Island to Grant's tomb and return.

Meanwhile we may go back to September, 1908, and note some of Orville Wright's performances. He had at Washington the same general arrangement, consisting of a launching rail, launching derrick, and an apparatus for hoisting up the weights



Fig. 10.—Wilbur Wright at Rome.

in order to give the machine impetus. This aeroplane is 40 ft. across and has a breadth of  $6\frac{1}{2}$  ft. The front rudder is 16 ft. long,  $2\frac{1}{2}$  ft. broad, and is equipped with skids, as shown in Fig. 7. The propeller is of peculiar and original construction and the motor is in every way the Wrights', for, in 1902, they made a canvass of the different makers of gasoline motors in this country, asking them to furnish a motor according to specifications which they presented. None of them at that time could do so and the Wrights went to work themselves, designed a motor, and built it with their own hands. This design has proven more reliable than the motors built in France, which are unduly light. The Wright motor, originally of 15 lb. to the horse-power, was reduced to 7 or 8 lb. to the horse-power, while the French people are building motors weighing  $4\frac{1}{2}$  to 5 lb., but they do not prove as reliable, while the Wright motor has never given any trouble and has proven reliable in every respect.

Orville Wright made a number of unofficial tests in 1908: On the 8th of September he rose to a height of 100 ft. and flew 40 miles; on the 12th he made a little higher ascension, estimated by the army officers at 200 ft., and flew 50 miles in 1 hour and 15 minutes. Altogether that year he made 14 flights. On the morning of the 17th of September he made several short flights. In the afternoon of that same day he met with a terrible accident; his propeller broke while he and Lieutenant Selfridge were in mid-air, the machine falling to the earth, when Orville

was seriously injured and Lieutenant Selfridge was killed. This ended the tests of that year. The government granted an extension of time and the trials were not resumed until July of this year (1909). The results this year, as you know, have been very successful. The official time test shows that on the 27th of July the machine remained in the air for 1 hour and 13 minutes, with two persons on board.

On the 30th of July the machine traveled 5 miles and back cross-country in 14 minutes, with two persons on board, at a speed which averaged over 42 miles an hour. Therefore, the machine was accepted by the government and a premium was given the Wrights of \$5,000 for the extra two miles of speed. Wilbur Wright is now engaged in teaching the army officers how to use the machine.

Immediately after the acceptance of the machine, Orville Wright went to Berlin, and there he has been accomplishing some remarkable feats.

On the 29th of August last he made his first exhibition there, flying 15 minutes. On the 8th of September he went up with Captain Hildebrandt; on the 18th of September he went up with Captain Englehardt, and on the 17th of September he made a demonstration before the court. On the 2d of October he took up into the air the Crown Prince, who gave him a handsome present, and on the 4th of October he made a flight of 21 miles, reaching a height estimated at 1,600 ft. This is the latest performance which he has made, although there is no telling what another day will bring forth. He is now in Paris. In London he may make some demonstrations with his machine in the course of a week or two.

The French, in 1905, became partly acquainted with what had been done in this country, and they thought it would never do to let the Americans obtain priority in the air, so a good many people began to experiment. Among the first was Santos Dumont, who made a flight on the 12th of November, 1906, of 720 ft. in 21 seconds with his No. 14 machine, Hargrave type. That flight created great excitement, and the French people thought they were on the high road to beat the Americans, but it required a good deal of further experimenting before that result was even partially accomplished.

Santos Dumont brought the machine out a second time but broke it. He then concluded that it was not built on the right plan and began to experiment with a modified machine. It proved unsatisfactory in various ways, and after it was broken he discarded it.

The next machine he tried was the biplane, the cellular partitions being removed. That ought, in my judgment, to have given satisfaction, but it did not and he abandoned it,

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although with that machine he made a flight, in Paris, on the 17th of November, 1907, of 500 ft.

He then went over to still another plan which he called the "Bird of Prey." In this design he placed the motor up in the top and had a dihedral angle in the biplane. But that did not give him satisfaction, and in the next machine he finally went over to the monoplane, which the French people have always insisted was the best design for a flying machine, and which they have promoted as against the biplane.

Figure 11 is a view of the monoplane of Santos Dumont, and with that, on the 10th of March, 1909, he made a flight of 1,300



Fig. 11.—Side View of Santos-Dumont's "Demoiselle."

ft. On the 10th of April he made another flight of 1.2 miles. On the 19th of June he made a flight at Issy, near Paris, of 820 ft., at which time his machine was struck by a downward rush of air, and to his great astonishment he found himself suddenly on the ground. The machine had gone down without his knowing what was happening. Fortunately the machine was not broken and he was not injured.

Santos Dumont's idea had been all along to have a handy machine, and he finally built a baby monoplane, which he called the "Demoiselle" (Dragon Fly). This is the smallest of all the existing aeroplanes. Its supporting surface is only 97 sq. ft.; its weight 260 lb. When that is compared with the Wright machine, which has 500 sq. ft. of supporting surface and a weight of 950 lb. (the empty machine), we can appreciate the enormous difference and the necessity, therefore, of driving this Dragon Fly very much faster in order to obtain support from the air, with so very small a surface. On the 13th of September of this year, near Paris, Mr. Dumont was able to drive that machine five miles in five minutes, going down the wind, or at the rate of 60 miles an hour over the ground. The speed through the air was probably about 50 miles an hour. Fig. 12 is from a photograph taken during that flight, which was from St. Cyr to Buc. I think the general idea is sound, for the smaller the flying machine can be made, within limits, the faster it must be made to go, and the more useful it is likely to prove for varying wind conditions. Commercially I have no clear opinion as to its uses, but as a mode of rapid trans-

portation for very light loads, I think the smaller the aerial plane the better.

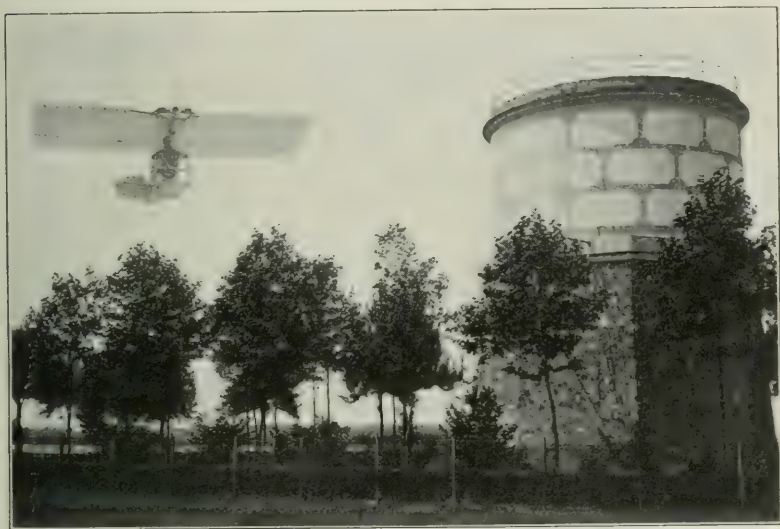


Fig. 12.—Santos Dumont. St. Cyr to Buc.

As regards the question which has lately been debated extensively, of the relative merits of the biplane and monoplane, I do not think we are yet in position to decide which is the better design. Both have their good points. The monoplane offers less resistance, but the biplane is steadier, stiffer, and stronger in every way. So it is only experience that will determine which one is the most efficient.

Other experimenters have come into the field, and among the first was a clever young sculptor by the name of Leon Delagrangé. He went to Voisin brothers and asked them to build him an *aéroplane*. This was called the Delagrangé machine, but as a matter of fact the designing and construction was done by the Voisin brothers, who are a leading authority on the subject of building flying machines, and who, in two years, have had to enlarge their shop three times to keep up with their orders.

In Fig. 13 is shown the machine the Voisin brothers built for Delagrangé. At first he did not trust himself to fly the machine, but got Voisin to ride in it and show him how. Subsequently he flew in it himself and all the later feats he has accomplished by himself.

On the 11th of April, 1908, he flew 2.5 miles at Issy; on the 27th of May, at Rome, 7.9 miles in 15 minutes and 26 seconds; at Milan, June 22d, 10.5 miles in 16 minutes and 30 seconds.  
April, 1910

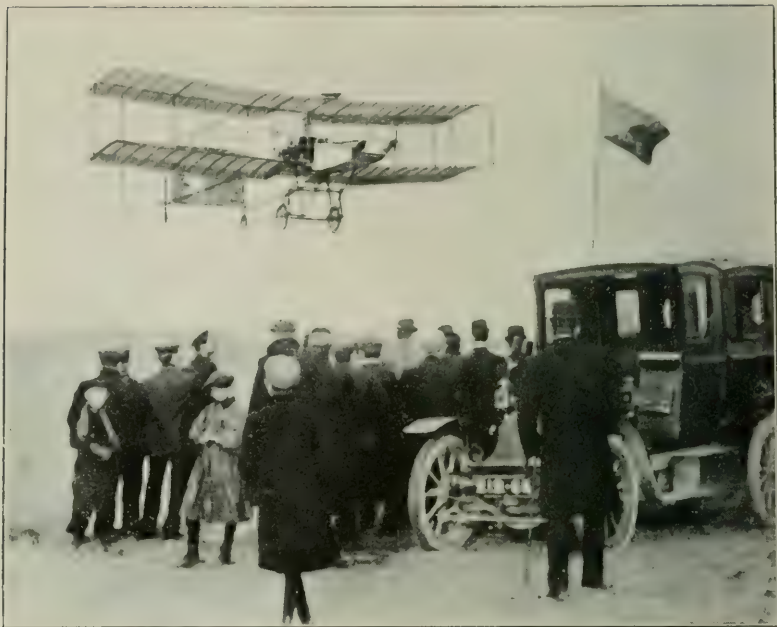


Fig. 13.—Delagrange on the Voisin Machine.

onds. Then he went to Turin and for the first time in history took a lady on board, who was very proud of the honor.

The picture, Fig. 14, is from the meet at Rheims in August, 1909, where Delagrange flew 31 miles on a monoplane. It may

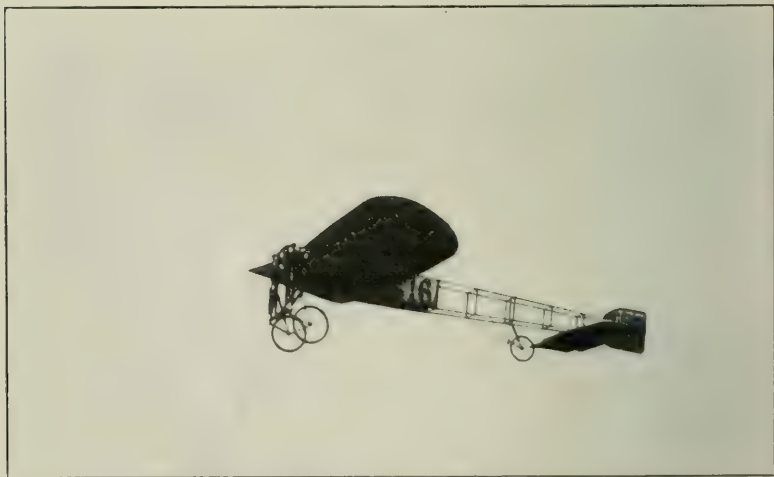


Fig. 14.—Delagrange on a Monoplane.

be remarked incidentally that there have been lately quite a number of these tournaments in Europe, which have attracted great crowds, have proved very satisfactory, and where all previous records have been smashed. One was at Rheims, where the Champagne people contributed large sums for the experiments. Another tournament took place later in Berlin, and still another in Juvisy, near Paris, in October, 1909.

The next man to gain prominence was the celebrated sportsman, Henry Farman, who walked into the Voisin shop one day and ordered an aeroplane. He succeeded, on the 26th of October, 1907, in flying 253 ft., which at that time was considered a great feat. He then attempted to sweep a circle, but did not succeed. It really took the French people two years to learn how to turn a corner. They were somewhat misled at first by a mathematical equation, and then closely analyzed the motions of the bird. They found that he flexed one wing at a lower angle than the other, placing himself thereby on a slant, so that the centripetal force of gravity should overcome the centrifugal force of the speed, and that similar effects could be produced by side fins and wing tips. Since that time they have turned corners without great difficulty but only on long radii.

Mr. Farman was successful, among other things, in sweeping curves on the 6th of July, 1908, when he flew 12 miles in 19 minutes and won the Armengaud prize which had been offered for the first turning of a corner. One of his flights is shown in Fig. 15.



Fig. 15.—Henry Farman's Biplane in Flight.

On the 30th of October he made the first cross-country flight in history, by going from Chalons to Rheims, 17 miles in 20 minutes, thus winning great applause and becoming the foremost aviator in France. In 1909 he designed and built a flying machine of his own with which to compete at the Rheims tournament.

He put both skids and wheels in this, the wheels being so adjusted that they could be lifted up, and with that apparatus splendid results were obtained in the Champagne tournament. The apparatus is shown in Fig. 16.



Fig. 16.—Farman's New Machine Wins First Prize.

On the 18th of July that machine flew for 1 hour and 23 minutes at Chalons. On the 23d of July he took a cross-country trip covering 40 miles from Chalons to Suippe. On the 27th of August his machine made a flight of 112 miles at Rheims, which is the world's record for distance at present,\* and he received, therefore, the first prize in that tournament. On the same day the machine flew 6 miles in 10 minutes with three persons on board, this being the first time three persons had ridden in a flying machine.

The next experimenter to be mentioned is Louis Blériot. He began his experiments in 1906, and has built and broken more

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\*Since this talk, Mr. Farman made, on the 3d day of November, 1909, a flight officially estimated as 137 $\frac{1}{4}$  miles in 4 hours 6 minutes and 25 seconds, but really of 150 miles, over the aviation grounds at Mourmelon.

machines than any other aviator in the world. He has built twelve machines and broken about fifteen, that being accomplished by rebuilding the same machine after smashing it. He is a man of tremendous pluck and wonderful imagination, and therefore tries all sorts of things. The machine with elliptical cells was launched on floats in the Seine in order to haul it up as a kite, and was Blériot's third. He had an idea that this elliptical arrangement would increase the stability very much, but it did not, and he gave up that idea. He then constructed No. 4, which he called a box-plane.

Machine No. 5 was of the Langley type, on the same plan that our army officers had been unable to obtain further funds to experiment with—two sets of wings, one behind the other—he placed it on wheels, and with that type he got some very fair flights, flying 474 ft. That was not enough for him, so he went from that to the monoplane and he has built, I think, six of them. Since then he has adhered to the so-called Dragon Fly plan and is now flying on No. 12. On the 13th of July, 1909, he flew 27 miles in 45 minutes. Fig. 17 shows the machine on which he made his journey cross-country from Etampes to



Fig. 17.—Blériot's Monoplane. Across Country.

Chevilly, a distance of 27 miles, and on that occasion he flew across a railway train, over one of the churches, and over various buildings.

On the 25th of July Blériot attempted to cross the British channel and succeeded. Fig. 18 is from a photograph taken on that occasion. That trip comprised a distance of 33 miles and was made in 37 minutes. It created great excitement, great ap-



Fig. 18.—Blériot's Monoplane. Across Channel.

plause, and great wonder, although, as a matter of fact, it was perhaps not as difficult a feat as the previous flying across-country, but it appealed very much more to the imagination.

Blériot then went to the meeting at Rheims in Champagne, and there exhibited some very good performances. He flew over the grandstand at a very great height, made a trip on the 27th of August of 25 miles in 41 minutes, winning the ninth prize for distance, while on the succeeding day he flew 6 miles in 7 minutes and 48 seconds, winning the first prize for speed.†

The next man who began experimenting was Mr. Esnault-Pelterie, a young French civil engineer, who started out with gliding machines, and then built a monoplane. Fig. 19 gives a view of the 1908 design. That is the machine as finally per-



Fig. 19.—Three-quarters View of the R. E. P. Monoplane.

The wing wheels *b b* and the twisting rudder *h* are features of this machine.

fect. He has made quite a number of flights, but no very long ones nor any high ones, the highest being 100 ft.

Captain Ferber, who is next to be mentioned, has been the chief apostle of aeroplanes in France. He became interested in the subject at an early date (1898), and has been promoting aeroplanes ever since. He began with gliding experiments. At first he was greatly in favor of the monoplane, but when I explained to him the advantages of the biplane, he accepted that design, although he did not like the stiff, horizontal lines, and introduced bird-like transversal curves. Then he added a motor; this was applied to the No. 9 machine, in which he still had these transversal curves in the wings; he had the propeller in front, and instead of twisting the wings he used fins at the rear, which are adjustable. He obtained some very fair results. This machine is shown on Fig. 20. On the 5th of September, 1909, he

†Subsequently, December 12, 1909, he was driven against a house during an exhibition flight at Constantinople, met with his twenty-second fall, and sustained injuries sufficiently severe, though not fatal, to require his going to a hospital.

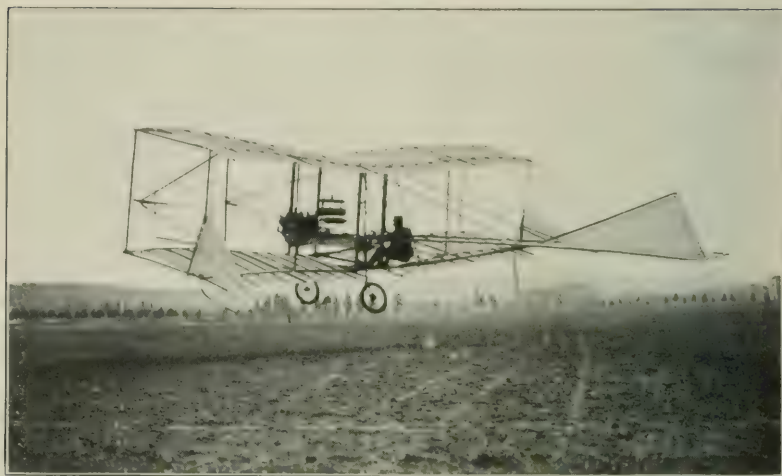


Fig. 20.—Ferber's Biplane in Full Flight.

borrowed a Voisin machine and undertook a trial flight at Boulogne, preliminary to attempting to cross the British channel, where it is about 40 miles wide, but, in making a turn, his machine tipped over unduly to the left. He undertook to alight, but in doing so his left wing struck a lump of earth, or hummock, when the wheels rolled into a ditch, the machine turned turtle, and poor Ferber was killed, to the profound sorrow of all interested in aviation. He is the third victim thus far this year,‡ but the wonder all along has been that so few accidents have occurred. There have been thousands of flights made—for instance, 1,300 were made in one week at the Rheims tournament—but thus far only three deaths have occurred.

More people kept coming into the field, and among the later ones is Mr. Hubert Latham, with a monoplane called the "Antoinette." Mr. Latham has risen to sudden prominence by some daring feats. Mr. Levavasseur designed and built this monoplane and engaged Mr. Latham to operate his machine. With it Mr. Latham got some very fine flights, such as that shown in Fig. 21 taken at Rheims. On the 6th of June, 1909, he went across the country 10 miles from Juvisy. On the 19th of July he attempted to cross the British channel, but was unsuccessful. On the 27th of July he tried it again, and flew 20 miles, or within one mile of Dover; the motor then gave out and he fell into the sea, the rescue being shown on Fig. 22. On the 26th of August, at the meeting at Rheims, he flew 96 miles in two hours and 18 minutes, and won the second prize for distance. On that occa-

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‡Since then Aviator Fernandez was killed at Nice, December 6th, by a fall in his aeroplane.

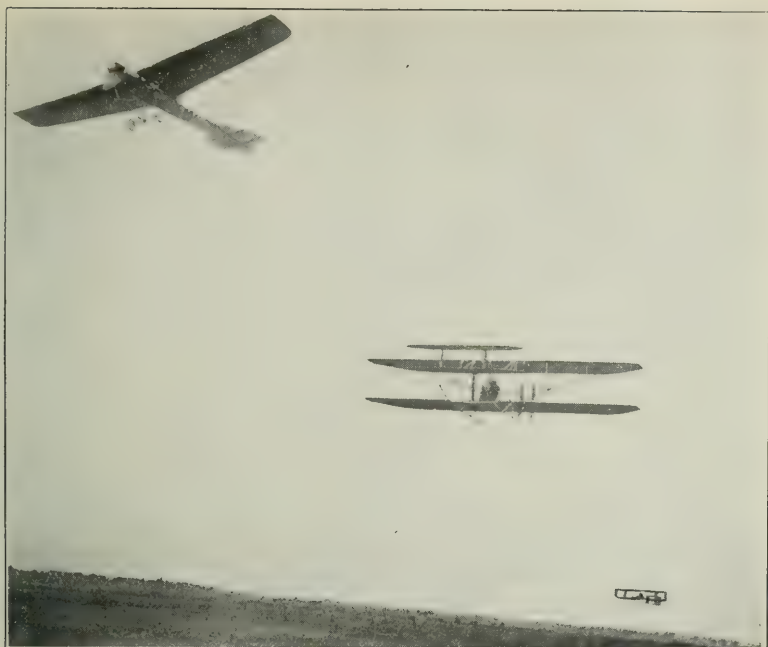


Fig. 21.—Latham (at top). Lefebvre and Bunau-Varilla.



Fig. 22.—Latham's Antoinette Monoplane in the English Channel and the Rescue.

sion he rose 508 ft., a record which has since been beaten by Paulhan and Rougier, who have developed an extraordinary aptitude for high flights.

On his first attempt, on the 10th of July, 1909, Paulhan was able to fly 1.25 miles. On the 19th of July he flew 12 miles across-country; on the 7th of August, 23 miles; on the 24th of August, 18 miles on a Voisin machine, and on the 25th of August he flew 81 miles at Rheims, winning third prize for distance. He has since made very fine flights in various meets. Fig. 23 is from a photograph taken at Juvisy.



Fig. 23.—Paulhan on Voisin Machine at Rheims.

The next man to reach prominence is Mr. Sommer. On the 4th of August, 1909, he flew 2 hours; on the 27th of August, 37 miles at Rheims; on the 10th of September, 18 miles over troops in review; on the 11th of September, 24 miles, from Nancy to Lenoncourt. Fig. 24 shows a flight in company with Farman.

E. Lefebvre, an automobile dealer, having purchased a Wright machine, laid down lines of rails and taught himself how to operate and fly the machine. At Rheims he made some very good performances. On the 27th of August he flew 12.5 miles in 20 minutes and 47 seconds. Unfortunately, upon the 7th of September, when testing a new Wright machine, he was upset and killed, this being the first fatal accident to occur in 1909.



Fig. 24.—Sommer and Farman in Race.

One of the last men to come into prominence in France has been Mr. Henri Rougier who operates a Voisin machine, Fig. 25, and who has made some remarkable high flights. At Brescia



Fig. 25.—Rougier's Voisin Rising from Starting Ground.

he reached 328 feet of altitude, and later, on another occasion, 650 feet of altitude was reached. At Berlin he won the first prize for distance. On the 18th of October, at Blackpool meeting in England, he made a flight of 18 miles in 25 minutes, but all of those performances in height fall far short of the performances of Orville Wright, who rose to a height of 1,600 ft.

By the contract in which the Wright brothers agreed to sell their French patents to a syndicate, Mr. Wilbur Wright was to teach three pupils to operate the machines. The men selected were the Count de Lambert, Mr. Paul Tissandier, and Captain Lucas-Girardville. The latter, being an army officer, has not appeared in any public tournament, but Mr. Tissandier has made many good flights, the longest up to the present time being one of 69 miles at Rheims and he has been training pupils of his own. Count de Lambert made a flight of 72 miles at Rheims, and day before yesterday (October 18th) he made a sensational journey from the aviation grounds at Juvisy, where Fig. 26 shows one of his flights, over a portion of Paris to the Eiffel tower and



Fig. 26.—De Lambert on Wright Machine.

back, some 30 miles. This feat, as well as the flight of Latham, on September 27th, over the suburbs of Berlin, is disfavored by the Wrights as involving undue risks of accident.

Wilbur Wright also taught two pupils in Italy (where he sold a machine).—Lieutenant Calderara, who flew at Rome and at Brescia, winning some prizes and meeting with accidents, and Lieutenant Savoya, whose performances have not been made known.

Mr. Legagneux and Mr. Bunau-Varilla also made creditable flights at Rheims upon machines built by Voisin brothers, but the performances most commented upon at that tournament were those of Mr. Glen Curtiss, who, with a machine built by himself, won the Gordon Bennett cup by making the shortest time over 20 kilometres; won the first prize for speed in a flight of 30 kilometres (46 miles an hour), and the second prize for speed over 10 kilometres, in which he flew at 48 miles per hour. Figs. 27 and 28 show these flights. Subsequently Mr. Curtiss won the grand prize at the Brescia meet by flying 31 miles in 49 minutes and 24 seconds. He had previously won twice the *Scientific American* trophy in this country, once, July 4, 1908, by a flight of 5,090 ft. at Hammondsport, N. Y., and again, July 24, 1909, by a flight of 25 miles in 52 minutes and 30 seconds.

This was the direct outcome of the labors of the *Aerial Experiment Association*, organized in 1908 by Alexander Graham Bell, upon the suggestion of Mrs. Bell, who generously contributed the funds. Dr. Bell had been experimenting with groupings of tetrahedral kites which exhibited extraordinary steadiness in the air. He hoped to develop them into an efficient flying machine of automatic stability and had been well served in his experiments by two young Canadian engineers, Mr. F. W. Baldwin and Mr. J. A. D. McCurdy. In order to give these faithful men a chance to test their own ideas the *Aerial Experiment Association*

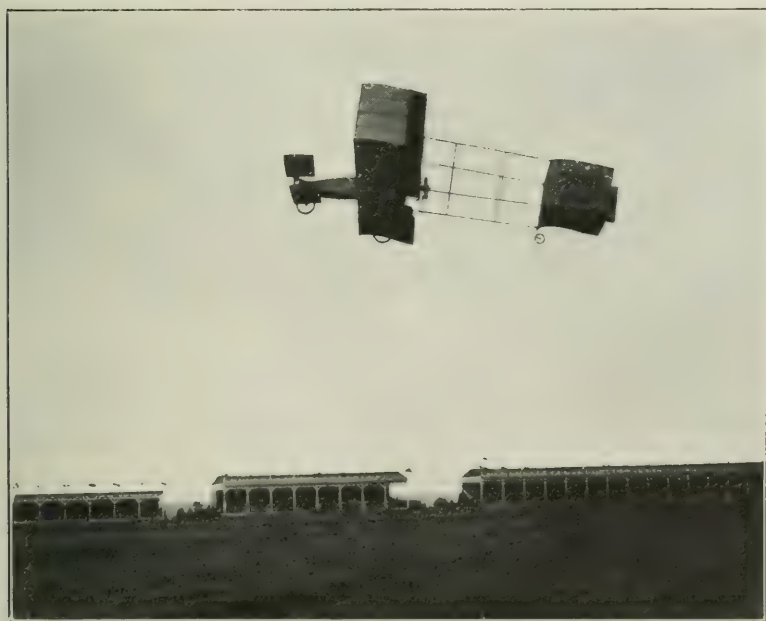


Fig 27.—Bunau-Varilla on Voisin Biplane.

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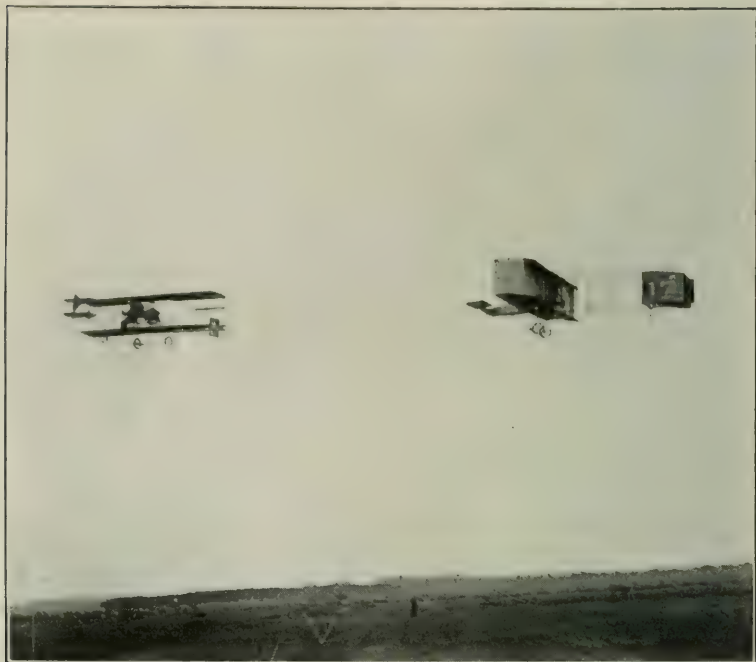


Fig. 28.—Curtiss and Bunau-Varilla.

was organized by taking in (besides the three named) Lieutenant Selfridge and Mr. Curtiss, the latter then being a manufacturer of motor-cycles and motors at Hammondsport, N. Y., where the experiments were first started. The association built four flying machines—the *Red Wing*, the *White Wing*, the *June Bug* and the *Silver Dart*—all of double bowed shape, shown in Fig. 29, and



Fig. 29.—The "June Bug" at Hammondsport, N. Y.

equipped with Curtiss motors. With these some very promising flights were made, both at Hammondsport and at Baddeck, Nova Scotia, to which the association removed and where Mr. McCurdy made flights of 16 miles and over.

I have memoranda of many more flights that have been made by other aviators, but I think they will be of less interest than the moving pictures about to be shown.

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Editor's Note: The talk was illustrated by many beautiful and interesting scenes, exhibited by the stereopticon, which are virtually, though not necessarily exactly, the engravings printed in this paper. At the close of the address, some beautiful and wonderful views of different machines in flight were shown by the aid of a moving-picture machine installed that evening for the purpose.

Figs. 1, 2, 3, 4, 5, 6, 7, 11, 15, 19, 22 and 25 are from Victor Loughheed's "Vehicles of the Air," kindly loaned by the Reilly and Britton Company, publishers.

The following table, compiled by the Author, is through the courtesy of The World Almanac, 1910:

## CHRONOLOGY OF AVIATION

(Compiled by O. Chanute.)

Bewildering advance in aviation took place in 1908 and 1909. When it is remembered that the first successful man flight, landing safely, was made by Wright brothers December 17, 1903, that it took them two years—1904-1905—to obtain entire control over their machine; that the Santos-Dumont flight of 720 feet, November 13, 1906, excited the wonder and admiration of all Europe, we can realize partially the progress made, now that flights of over 100 miles have been made, that a height of 1,600 feet is said to have been attained, that there are hundreds of successful experimenters in the field and that records are being broken every few days.

It would be quite futile to give a compendium of all the flights made in 1909. They number thousands. The profitable thing which can be done is to tabulate the more remarkable performances; and, in order to mark the advance, to include therewith the former feats of the same aviator, which excited wonder only one or two years ago. The most interesting of these are prefixed with a star.

During 1909 exhibitions of aviating apparatus were held in Paris, December 24-30, 1908; in London, March 19-27, in London again July 6 to August 4, in Frankfort July 10 to October 10, in Paris again September 25 to October 17, and these drew great crowds; while meets, contests and tournaments were held at Reims August 22 to 29, at Brescia September 5 to 20, at Berlin September 26 to October 3, at New York September 25 to October 2, at St. Louis October 4 to 10, at Paris October 2 to 21, and at Blackpool and at Doncaster, October 15 to 23.

The events which have attracted most attention have been the cross-country flight of H. Farman, from Bouy to Reims, 17 miles, without landing, October 30, 1908; of Bleriot, October 31, 1908, from Toury to Artenay and return with landings; of the same man from Etampes to Chevilly, 26 miles, July 13, 1909, and his flight across the British Channel, July 25; the two unsuccessful attempts of Latham to perform the same feat, July 19 and July 27, 1909; the flight of Farman July 23, from Chalons to Suippes, 40 miles; of his flights at Reims of 112 miles August 27, and of 150 miles at Mourmelon, November 3; of Orville Wright at Fort Myer, July 27 and 30; of W. Wright at New York October 4; of Curtiss at Reims August 28-29; of Latham over Berlin September 27 and of De Lambert over Paris October 18, as well as a speed of about 90 miles an hour down wind at Blackpool, attained by Latham October 22, 1909.

These feats have not been accomplished without some deplorable accidents. Several aviators have been killed or injured by the fall of their machines and many of the latter have been smashed. It will be remembered that Lieut. Selfridge was killed at Fort Myer, September 17, 1908. In 1909 Eugene Lefebvre was killed at Juvisy September 7; on the same day Enea Rossi was killed at Rome while testing a machine of his own invention; while on September 22 the distinguished propagandist of aviation in France, Capt. L. F. Ferber, was killed at Boulogne by an unlucky landing. On December 6 A. Fernandez, a French aviator of Spanish birth, was killed at Nice by the fall of his biplane, similar to Wright's, caused by the explosion of his motor when at a height estimated at 500 metres.

The tendency has been to develop special experts for exhibition flights. Some 200 of their flights, which are thought the more memorable for one reason or another, will be found in the following list:

# CHRONOLOGY OF MEMORABLE FLIGHTS—MOTOR AEROPLANES.

WILBUR WRIGHT.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
*Dec. 17, 1903.	Biplane.	Kitty Hawk.	852 ft.	0 00 59	1	First successful man flight in history.
Nov. 9, 1904.	Biplane.	Dayton, O.	3 miles	0 4 30	1	Made 105 flights that year.
Oct. 5, 1905.	Biplane.	Dayton, O.	24 miles	0 38 00	1	Made 49 flights that year.
Aug. 8, 1908.	Biplane.	Mans.	.....	.....	1	Short flights showing control.
*Sept. 21, 1908.	Biplane.	Auvours	41 miles	1 31 00	1	Made over 100 flights here.
Oct. 10, 1908.	Biplane.	Auvours	46 miles	1 9 00	2	With Mr. Painleve; took 35 others.
*Dec. 18, 1908.	Biplane.	Auvours	62 miles	1 54 00	1	Rose to 360 ft.; then world record.
*Dec. 31, 1908.	Biplane.	Auvours	77 miles	2 20 23	1	Won Michelin prize; world record.
Mar. 20, 1909.	Biplane.	Pau, France.	.....	6 00	1	No previous propulsion; teaches 3 pupils.
Apr. 16, 1909.	Biplane.	Rome	.....	.....	2	Took up many passengers.
Apr. 26, 1909.	Biplane.	Rome	.....	.....	1	No previous propulsion.
*Sept. 25, 1909.	Biplane.	New York.	.....	.....	1	Named Statue of Liberty.
*Oct. 4, 1909.	Biplane.	New York.	21 miles	0 33 33	1	To Grant's tomb and return.

ORVILLE WRIGHT.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
Sept. 8, 1908.	Biplane.	Fort Myer.	40 miles	0 62 00	1	Unofficial; rose to 100 feet.
*Sept. 12, 1908.	Biplane.	Fort Myer.	50 miles	1 15 00	1	Longest flight of 1908.
*Sept. 15, 1908.	Biplane.	Fort Myer.	3 miles	0 4 00	2	Selfridge killed; Wright injured.
July 20, 1909.	Biplane.	Fort Myer.	.....	1 20 00	1	Unofficial test.
July 21, 1909.	Biplane.	Fort Myer.	.....	1 29 00	1	Unofficial test.
*July 27, 1909.	Biplane.	Fort Myer.	.....	1 13 00	2	Official time test; machine accepted.
*July 30, 1909.	Biplane.	Fort Myer.	10 miles	0 14 00	2	Official speed test; 42 miles per hour.
Aug. 29, 1909.	Biplane.	Berlin	.....	0 15 00	1	Many preliminary exhibitions.
Sept. 4, 1909.	Biplane.	Berlin	.....	0 55 00	1	With Capt. Hildebrandt.
Sept. 8, 1909.	Biplane.	Berlin	.....	0 17 00	2	With Capt. Englehardt.
Sept. 9, 1909.	Biplane.	Berlin	.....	0 15 00	2	In presence of Empress rose to 565 ft.
Sept. 17, 1909.	Biplane.	Berlin	.....	0 54 26	1	With Capt. Englehardt.
*Sept. 18, 1909.	Biplane.	Berlin	.....	1 35 47	2	With Crown Prince of Germany.
Oct. 2, 1909.	Biplane.	Berlin	.....	0 10 00	2	Reached h'ght of 1,600 ft.; unofficial world rec'd.
*Oct. 4, 1909.	Biplane.	Berlin	21 miles	0 33 33	1	

## A. SANTOS DUMONT.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
*Nov. 13, 1906...	Cellular.....	Bagatelle .....	720 ft.	0 21 00	1	First flight in Europe.
Nov. 17, 1907...	Biplane.....	Issy .....	500 ft.	.....	1	Made several flights.
Nov. 21, 1907...	Monoplane.....	Bagatelle .....	400 ft.	.....	1	Made several flights.
Mar. 10, 1909...	Monoplane.....	Bagatelle .....	1,300 ft.	.....	1	With the Libellule.
Apr. 10, 1909...	Monoplane.....	St. Cyr.....	1.2 miles	.....	1	With the Demoiselle.
June 19, 1909...	Monoplane.....	Issy .....	820 ft.	.....	1	Several other flights.
*Sept. 13, 1909...	Monoplane.....	St. Cyr.....	5 miles	0 12 00	1	St. Cyr to Buc to visit friend.
*Sept. 17, 1909...	Monoplane.....	St. Cyr.....	10 miles	0 16 00	1	Across country.

## LEON DELAGRANGE.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
Mar. 16, 1907...	Biplane.....	Bagatelle .....	30 ft.	.....	1	First Voisin aeroplane.
*Mar. 29, 1908...	Biplane.....	Ghent .....	453 ft.	.....	2	First flight with passenger (Farman).
Apr. 11, 1908...	Biplane.....	Issy .....	2.43 miles	0 6 30	1	Won Archdeacon cup.
May 27, 1908...	Biplane.....	Rome .....	7.90 miles	0 15 26	1	In presence of King, etc.
May 22, 1908...	Biplane.....	Milan .....	10.50 miles	0 16 30	1	Best flight on Italian trip.
*July 8, 1908...	Biplane.....	Turin .....	500 ft.	.....	2	First woman passenger (Mrs. Peltier).
Sept. 6, 1908...	Biplane.....	Issy .....	15.2 miles	0 29 53	1	Beat then existing records.
May 23, 1909...	Biplane.....	Juvissey .....	3.6 miles	0 10 18	1	Won Lagatineri prize.
June 12, 1909...	Biplane.....	Juvissey .....	3.7 miles	.....	1	Circling across country.
Aug. 23, 1909...	Monoplane.....	Reims .....	.....	0 11 4	1	Won tenth prize; speed.
Aug. 27, 1909...	Monoplane.....	Reims .....	31 miles	.....	1	Won eighth prize; distance.
Sept. 15, 1909...	Monoplane.....	Denmark .....	.....	0 15 00	1	Before King, at Aarhus.
Oct. 16, 1909...	Monoplane.....	Doncaster .....	5.75 miles	0 11 25	1	To keep crowd from grumbling.
*Oct. 26, 1909...	Monoplane.....	Doncaster .....	6 miles	0 7 36	1	Over 50 miles an hour.

HENRY FARMAN.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
Oct. 26, 1907...	Biplane .....	Issy .....	253 ft.	.....	1	First sweeps a half circle.
May 30, 1908...	Biplane .....	Ghent .....	0.77 miles	.....	2	With Mr. Archdeacon.
July 6, 1908...	Biplane .....	Ghent .....	12.2 miles	0 19 3	1	Won Armengaud prize.
*Oct. 30, 1908...	Biplane .....	Chalons .....	17 miles	0 29 00	1	Cross country. Chalons to Reims.
Oct. 31, 1908...	Biplane .....	Chalons .....	.....	0 23 00	1	Eighty-two feet altitude; won prizes.
July 18, 1909...	Biplane .....	Chalons .....	.....	1 23 00	1	His first long flight.
*July 23, 1909...	Biplane .....	Chalons .....	40 miles	1 5 00	1	Cross country, Chalons to Suippe.
*Aug. 27, 1909...	Biplane .....	Reims .....	112 miles	3 4 57	1	First prize for distance and time up.
Aug. 27, 1909...	Biplane .....	Reims .....	6 miles	0 10 00	3	With two passengers; won prize.
*Oct. 3, 1909...	Biplane .....	Berlin .....	62 miles	1 40 00	1	Won third prize, \$960.
Oct. 18, 1909...	Biplane .....	Blackpool .....	14 miles	0 23 00	1	On first day of meeting.
*Oct. 20, 1909...	Biplane .....	Blackpool .....	47 miles	1 32 16	1	Won prize of \$10,000.
*Nov. 3, 1909...	Biplane .....	Mourmelon .....	137.25 miles	4 6 25	1	Said to be 150 miles; 4h. 17m. 35s.

LOUIS BLERIOT.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
Aug. 6, 1907...	Langley .....	Issy .....	470 ft.	.....	1	His first attempt to circle.
July 4, 1908...	Monoplane .....	Issy .....	3.7 miles	0 5 47	1	Swept several circles.
Oct. 21, 1908...	Monoplane .....	Toury .....	4.25 miles	0 6 40	1	At height of 65 feet.
Oct. 31, 1908...	Monoplane .....	Toury .....	8.7 miles	0 11 00	1	Toury to Artenay, landed.
Oct. 31, 1908...	Monoplane .....	Toury .....	8.7 miles	.....	1	Artenay to Toury; intermediate landing.
May 30, 1909...	Monoplane .....	Issy .....	8.7 miles	.....	1	Over the adjoining fields.
*June 12, 1909...	Monoplane .....	Juvissey .....	984 ft.	.....	3	Santos Dumont and Fournier as passengers.
*July 13, 1909...	Monoplane .....	Mondésir .....	26 miles	0 44 30	1	Estampes to Chevilly, cross country.
*July 25, 1909...	Monoplane .....	Calais .....	32 miles	0 37 00	1	First flight across British Channel.
*Aug. 28, 1909...	Monoplane .....	Reims .....	6.3 miles	0 7 48	1	Won first prize speed for 6-mile trip.
Aug. 27, 1909...	Monoplane .....	Reims .....	25 miles	0 41 00	1	Won ninth prize for distance flown.

S. F. CODY.					
DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.
Feb. 22, 1909...	Biplane	Aldershot	1,200 ft.	.....	1
May 14, 1909...	Biplane	Aldershot	1 mile	.....	1
July 21, 1909...	Biplane	Aldershot	4 miles	.....	1
Aug. 29, 1909...	Biplane	Aldershot	10 miles	.....	2
*Sept. 8, 1909...	Biplane	Aldershot	40 miles	1 3 00	1
Sept. 11, 1909...	Biplane	Aldershot	.....	.....	1
Oct. 16, 1909...	Biplane	Doncaster	3,000 ft.	.....	1
MOORE-BRAZON.					
DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.
Jan. 28, 1909...	Biplane	Chalons	3.1 miles	.....	1
Feb. 24, 1909...	Biplane	Issy	1.2 miles	.....	1
Feb. 28, 1909...	Biplane	Issy	2.5 miles	.....	1
April 30, 1909...	Biplane	England	4.5 miles	.....	1
Oct. 30, 1909...	Biplane	Shell Beach	.....	.....	1
L. F. FERBER.					
DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.
Aug. 8, 1908...	Biplane	Issy	.....	.....	1
Sept. 19, 1908...	Biplane	Issy	1,640 ft.	.....	1
June 13, 1909...	Biplane	Juvissey	3.1 miles	0 5 30	1
*Sept. 15, 1909...	Biplane	Boulogne	6 miles	0 9 00	1
Sept. 22, 1909...	Biplane	Boulogne	1 mile	.....	1
ESNAULT PELTIERE.					
DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.
Oct. 19, 1907...	Monoplane	Buc	.....	.....	.....
June 8, 1908...	Monoplane	Buc	0.75 miles	.....	1
Remarks.					
In a 12-mile wind. On the army biplane. On rebuilt machine. With passenger in three flights. Circuit to Farnborough and return. Before Empress Eugenie. Machine wrecked; aviator hurt.					
Learning use of Voisin machine. Swept over two circles. Several flights. Gradually improves performances. Won Daily Mail \$5,000 prize for flight with a British machine.					
First trials with motor machine. His aeroplane No. 9. On a Voisin machine. Boulogne to Wimereux. Landed in ditch; killed.					
First short flights. At height of 100 ft.					

HUBERT LATHAM.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
May 19, 1909...	Monoplane	Chalons	1,640 ft.	1 7 37	1	Begins operating the Antoinette.
June 5, 1909...	Monoplane	Chalons		1 7 37	1	In wind and rain; breaks record.
June 6, 1909...	Monoplane	Juvissey	10 miles		1	Cross country flight.
June 12, 1909...	Monoplane	Juvissey	30 miles	0 39 00	1	Won Goupy prize.
* July 19, 1909...	Monoplane	Calais	11 miles		1	Over British Channel; fell in sea.
* July 27, 1909...	Monoplane	Calais	20 miles		1	British Channel; fell near Dover.
* Aug. 26, 1909...	Monoplane	Reims	96 miles	2 18 9	1	Won second prize for distance.
* Sept. 27, 1909...	Monoplane	Reims			1	Won first prize altitude, 508 ft.
Sept. 29, 1909...	Monoplane	Berlin	6.5 miles	0 13 00	1	Across suburbs of Berlin.
Sept. 30, 1909...	Monoplane	Berlin	42 miles	1 10 00	1	Won second prize for distance.
* Oct. 22, 1909...	Monoplane	Blackpool	51 miles	1 23 00	1	Machine broken in landing.
Nov. 19, 1909...	Monoplane	Chalons			1	Flew in gale; won prize, \$1,500.
Dec. 1, 1909...	Monoplane	Mourmelon		10	1	Rose 1,345 ft., competing, Weiler prize.
					1	Rose 1,500 ft. in 40-mile wind.

LOUIS PAULHAN.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
* July 10, 1909...	Biplane	Douai	1.25 miles	1 17 00	1	His very first flight.
July 15, 1909...	Biplane	Douai		0 22 53	1	Reached altitude of 357 ft.
* July 19, 1909...	Biplane	Douai	12.1 miles	1 17 19	1	Cross country, Douai to Arras.
July 23, 1909...	Biplane	Douai	43.5 miles	0 18 20	1	Official allowance, 30 miles.
Aug. 6, 1909...	Biplane	Dunkerque		0 33 00	1	Altitude, 200 ft.
Aug. 7, 1909...	Biplane	Dunkerque	23 miles	0 38 12	1	On a Voisin biplane.
Aug. 25, 1909...	Biplane	Reims	18.6 miles	0 38 12	1	Altitude, 295 ft.
* Aug. 25, 1909...	Biplane	Reims	81 miles	2 43 24	1	Won third prize for distance.
Sept. 9, 1909...	Biplane	Tournai	12.4 miles	0 17 00	1	Two cross country flights.
* Sept. 13, 1909...	Biplane	Tournai		1 35 00	1	Tournai to Taintignies and return.
Sept. 17, 1909...	Biplane	Ostend	1.24 miles	0 3 16	1	Circled over sea.
Sept. 18, 1909...	Biplane	Ostend		1 1 1	1	Over sea front; won \$5,000 prize.
Sept. 10, 1909...	Biplane	P. Aviation	21.5 miles	0 21 48	1	Flew over line of the stands.
Oct. 12, 1909...	Biplane	P. Aviation	3.6 miles	0 6 11	1	Won prize for slowest flight, \$600.
Oct. 15, 1909...	Biplane	Blackpool	14 miles	0 25 53	1	On first day of Blackpool meeting.
* Oct. 19, 1909...	Biplane	Blackpool	15.75 miles	0 32 18	1	Won third prize for distance, \$1,400.
Nov. 19, 1909...	Biplane	Chalons			1	Rose 1,210 ft., competing, Weiler prize.
* Nov. 20, 1909...	Biplane	Mourmelon	37 miles	0 55 00	1	Chalons and return. Rose nearly 1,000 ft.

## ROGER SOMMER.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
July 4, 1909...	Biplane	Chalons	3.75 miles	.....	1	On Farman's new machine.
July 18, 1909...	Biplane	Chalons	.....	1 4 00	1	Longest of several flights.
* July 27, 1909...	Biplane	Chalons	25 miles	1 23 30	1	To Vadenay and back.
Aug. 1, 1909...	Biplane	Chalons	.....	1 50 30	1	Beats all French records.
* Aug. 2, 1909...	Biplane	Chalons	9 miles	0 12 00	1	To Suippes; 45 miles an hour.
Aug. 4, 1909...	Biplane	Chalons	.....	2 0 10	1	Trying to beat Wright's record.
* Aug. 7, 1909...	Biplane	Chalons	.....	2 27 15	1	Beats Wright's record of December 31, 1908.
Aug. 22, 1909...	Biplane	Reims	.....	1 19 33	1	On first day of Reims tournament.
Aug. 27, 1909...	Biplane	Reims	37 miles	.....	1	Won seventh prize for distance.
Sept. 6, 1909...	Biplane	Nancy	25 miles	0 35 00	1	Also made flights with passengers.
Sept. 10, 1909...	Biplane	Nancy	18 miles	.....	1	Accompanies troops on review.
Sept. 11, 1909...	Biplane	Nancy	24 miles	.....	1	Nancy to Lenoncourt.
Oct. 16, 1909...	Biplane	Doncaster	9.7 miles	0 21 45	1	Best flight in Great Britain to date.
* Oct. 26, 1909...	Biplane	Doncaster	29.7 miles	0 44 53	1	Won Whitworth cup.

## M. ELLEHAMMER.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
1906-1909	Biplane	Denmark	.....	.....	1	Experience with varied success.

## ALEXANDER GRAHAM BELL.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
1907-1909	.....	Baddeck	.....	.....	....	Experiments; tetrahedral machine.

## COUNT DE LAMBERT.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
Mar. 17, 1909...	Biplane	Pau	.....	0 3 00	1	First flight alone; Wright's pupil.
Mar. 24, 1909...	Biplane	Pau	15.6 miles	0 27 11	1	Wins Aero Club prize for 250 metres.
Mar. 27, 1909...	Biplane	Pau	.....	0 7 56	1	Flies beyond experimental field.
April 13, 1909...	Biplane	Pau	.....	0 1 30	2	With Delagrang as passenger.
* Aug. 26, 1909...	Biplane	Reims	72 miles	1 52 00	1	Won fourth prize; distance.
* Oct. 18, 1909...	Biplane	Juvissey	31 miles	0 49 39	1	To Eiffel Tower and back across Paris.
Oct. 21, 1909...	Biplane	Pt. Aviation...	1.25 miles	0 1 57	1	Wins \$3,000 prize for speed.

PAUL TISSANDIER.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
May 20, 1909...	Biplane	Pau	35.7 miles	.....	1	Pupil of W. Wright.
*Aug. 22, 1909...	Biplane	Reims	18.6 miles	0 29 00	1	Won third prize for speed over 30 kilometres.
*Aug. 27, 1909...	Biplane	Reims	69 miles	1 46 32	1	Won sixth prize for distance flown.

E. LEBEVRE.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
July 21, 1909...	Biplane	La Haye	2 miles	.....	1	Self taught on Wright machine.
*Aug. 27, 1909...	Biplane	Reims	12.4 miles	0 20 47	1	Shows great boldness and skill.
Aug. 28, 1909...	Biplane	Reims	.....	0 11 5	2	Performs evolutions with passenger.
Sept. 7, 1909...	Biplane	Juvissey	1,800 ft.	.....	1	Upset and killed.

MARIO CALDERARA.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
April 28, 1909...	Biplane	Rome	.....	0 10 00	1	Pupil of W. Wright.
May 6, 1909...	Biplane	Rome	.....	.....	1	Upset and hurt.
Sept. 12, 1909...	Biplane	Brescia	6.3 miles	.....	2	One passenger; won prize.
*Sept. 15, 1909...	Biplane	Brescia	5.6 miles	.....	2	Won Oldofredl prize.
*Sept. 20, 1909...	Biplane	Brescia	31 miles	0 50 51	1	Won second prize for speed.

GLEN N. CURTISS.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
*July 4, 1908...	Biplane	H'mondsp't	5,090 ft.	0 1 42	1	Wins Scientific American Cup.
July 13, 1909...	Biplane	Mineola	1.5 mile	0 3 00	1	Tuning up Aeronautic Society machine.
July 17, 1909...	Biplane	Mineola	15 miles	0 21 00	1	Described figure 8.
July 18, 1909...	Biplane	Mineola	30 miles	0 52 30	1	Official distance, 25 miles.
*July 24, 1909...	Biplane	Mineola	25 miles	0 52 30	1	Second winning Scien. American cup.
Aug. 24, 1909...	Biplane	Reims	6.2 miles	0 8 35	1	Wins second prize; speed over 10 kilometres.
Aug. 25, 1909...	Biplane	Reims	6.2 miles	0 8 11	1	Bleriot is 7 seconds faster.
Aug. 26, 1909...	Biplane	Reims	19 miles	0 29 00	1	Wins tenth prize; distance and speed.
*Aug. 28, 1909...	Biplane	Reims	12.4 miles	0 15 56	1	Wins Gordon Bennett cup.
*Aug. 29, 1909...	Biplane	Reims	18.6 miles	0 23 30	1	Wins first prize, speed over 30 kilometres.
*Aug. 29, 1909...	Biplane	Reims	6.2 miles	0 7 51	1	Wins second prize, speed over 10 kilo.
Sept. 11, 1909...	Biplane	Brescia	31 miles	0 49 24	1	Wins first prize for speed.
Sept. 29, 1909...	Biplane	New York	.....	.....	1	Flights about Governor's Island.
Oct. 10, 1909...	Biplane	St. Louis	.....	.....	1	Flights at Centennial celebration.
Oct. 16, 1909...	Biplane	Chicago	1 mile	0 1 30	1	Exhibition flights.

## J. A. D. MCCURDY.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
May 18, 1908...	Biplane	H'mondsp't	600 ft.	.....	1	With the White Wing.
July 4, 1908...	Biplane	H'mondsp't	3,420 ft.	.....	1	With the June Bug.
Feb. 23, 1909...	Biplane	Baddeck	2,640 ft.	.....	1	With the Silver Dart.
Feb. 24, 1909...	Biplane	Baddeck	4.5 miles	.....	1..	With the Silver Dart.
Mar. 11, 1909...	Biplane	Baddeck	19 miles	0 22 00	1	With the Silver Dart.
Mar. 18, 1909...	Biplane	Baddeck	16 miles	.....	1	Aggregate of 1,000 miles.
Aug. 2, 1909...	Biplane	Petawawa	20 miles	.....	1	Many flights; broke machine.

## LE BLON.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
Oct. 18, 1909...	Monoplane	Doncaster	22 miles	0 30 00	1	On Bradford cup; flew in rain.
Oct. 19, 1909...	Monoplane	Doncaster	15 miles	.....	1	Astonishing flight in a gale.
*Oct. 20, 1909...	Monoplane	Doncaster	.....	.....	1	Foolhardy flight in great gale.

## F. W. BALDWIN.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
Mar. 12, 1908...	Biplane	H'mondsp't	319 ft.	.....	1	With the Red Wing.
May 18, 1908...	Biplane	H'mondsp't	.....	.....	1	With the White Wing.
Mar. 18, 1909...	Biplane	Baddeck	.....	.....	1	With the Silver Dart.
Aug. 2, 1909...	Biplane	Petawawa	.....	.....	1	Several short flights.

## LEGAGNEUX.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
Feb. 14, 1909...	Biplane	Mourmelon	1.2 miles	.....	1	Pupil of Ferber.
Feb. 14, 1909...	Biplane	Mourmelon	6.2 miles	.....	1	Swamps two circles.
April 27, 1909...	Biplane	Vienna	2.5 miles	0 3 26	1	On a Voisin machine.
Aug. 6, 1909...	Biplane	Stockholm	3,280 ft.	.....	2	With a passenger.
Aug. 22, 1909...	Biplane	Reims	6 miles	0 9 56	1	Won eighth prize for speed over 6 miles.

## HENRI ROUGIER.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
May 23, 1909....	Biplane .....	Juvissey .....	18.6 miles .....	.....	1	Swept eleven circles.
Aug. 29, 1909....	Biplane .....	Reims .....	.....	.....	1	Won fourth prize; altitude, 180 ft.
Sept. 9, 1909....	Biplane .....	Brescia .....	.....	0 12 10	1	Reached 328 ft. altitude.
*Sept. 12, 1909....	Biplane .....	Brescia .....	31 miles .....	1 10 18	1	Reached 380 ft. altitude.
*Sept. 20, 1909....	Biplane .....	Brescia .....	.....	.....	1	Reached 650 ft. altitude.
*Sept. 28, 1909....	Biplane .....	Berlin .....	31 miles .....	0 54 00	1	Rises to 518 ft.
Sept. 29, 1909....	Biplane .....	Berlin .....	48 miles .....	1 35 00	1	In competition with Latham.
*Oct. 1, 1909....	Biplane .....	Berlin .....	80 miles .....	2 38 00	1	Wins first prize; distance.
Oct. 18, 1909....	Biplane .....	Blackpool .....	17.7 miles .....	0 24 43	1	Wins second prize; \$3,600.

## E. BUNAU-VARILLA.

DATE.	Machine.	Place.	Distance.	Time. H. M. S.	Per- sons.	Remarks.
Aug. 5, 1909....	Biplane .....	Chalons .....	.....	0 15 00	1	Voisin biplane presented by father.
Aug. 22, 1909....	Biplane .....	Reims .....	6.2 miles .....	0 13 30	1	Thirteenth prize for speed for 10 kilometres.
Aug. 29, 1909....	Biplane .....	Reims .....	18.6 miles .....	0 38 31	1	Eighth prize for speed for 30 kilo.

\*Considered the most interesting flights on record.

## THE CHICAGO HARBOR PROBLEM.

Report of the Committee, A. Bement, Chairman, and Messrs. W. L. Abbott, L. E. Ritter, E. C. Shankland and Willard A. Smith.

*Presented Wednesday, February 16, 1910.*

### TO THE WESTERN SOCIETY OF ENGINEERS—

GENTLEMEN:—In accordance with a resolution passed at a meeting of this Society held September 15th, 1909, that a committee be appointed by the President "to confer with committees of the City Council and others in regard to the work that is now being planned for the development of the Chicago Harbor, which committee shall report from time to time to the Society," the President, on October 4th, appointed the above members of the Society and this committee now offers its first report.

There are several features of the general harbor problem that the committee now considers that it is able to report upon. The first is a history of the volume of shipping at Chicago as compared with other lake ports. To this end, data from the report of the Chicago Harbor Commission\* have been employed as a basis of the accompanying diagrams, which present the growth and decline of shipping in a distinct and graphic manner. Other diagrams show certain phases of the grain business.

Figure 1 illustrates the freight tonnage handled at the various lake ports of which the Harbor Commission's report deals, including the Chicago and Calumet rivers, also the port of Chicago as a whole. Certain of the points used in plotting these curves, are the results of averages, as a considerable irregular fluctuation from year to year in the volume of traffic makes impossible a clear graphic presentation without smoothing out such peaks and hollows. Thus, the curves represent the average trend in development of the traffic at the various ports, and thus show without confusion, the relation between them. This method has been employed in plotting all of the curves shown.

It appears that water transportation at the port of Chicago was developed on a large scale before business at these other ports had become of much importance and increased at a rapid rate until 1890, at which time its real decline began. Thus Chicago today finds itself just where it was 20 years ago, notwithstanding the fact that the Calumet river, a part of the Port of Chicago, has made a very large increase, so that what has been gained at Calumet has been lost at the Chicago river.

Traffic in the Calumet at South Chicago has grown with approximately the same rate as that of the Milwaukee Harbor. While at Duluth and Cleveland it has increased to a much greater volume, the circumstances under which the large increase

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\* This Commission was composed of John M. Ewen, Chairman; Charles H. Conover, Isham Randolph, F. A. Delano, C. H. Wacker, Alderman Chas. M. Foell, Alderman Peter L. Hoffman, Alderman John P. Stewart, and Alderman C. E. Merriam, Secretary.

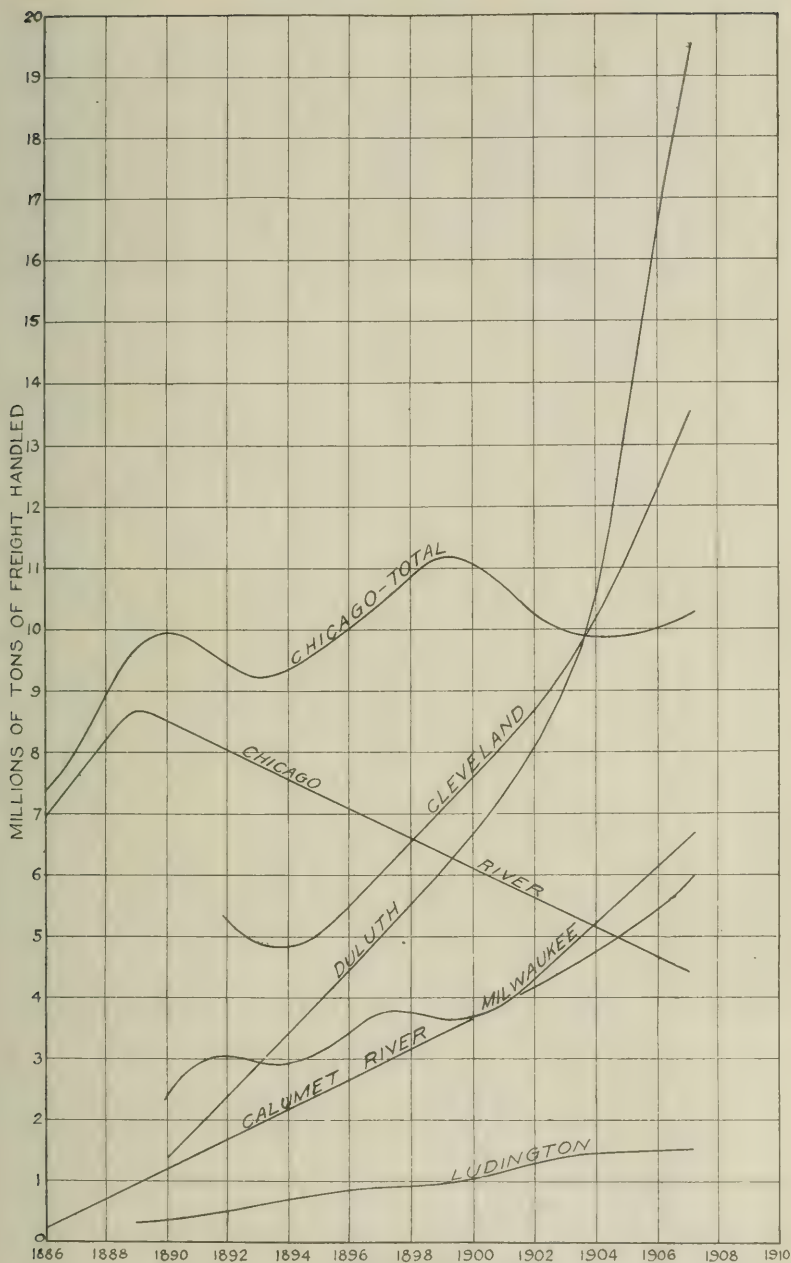


Fig. 1.—Volume of Commerce at Sundry Lake Ports.

at these two ports has occurred are, however, different from what they could have been at Chicago, even under ideal conditions. Thus, especially Duluth, is in no way properly comparable to Chicago. Therefore, Milwaukee has been taken as the port, whose situation renders it suitable as a basis to illustrate the loss at the Chicago river as shown by Fig. 2. In this connection Fig. 3 shows value of freight handled in the Chicago River.

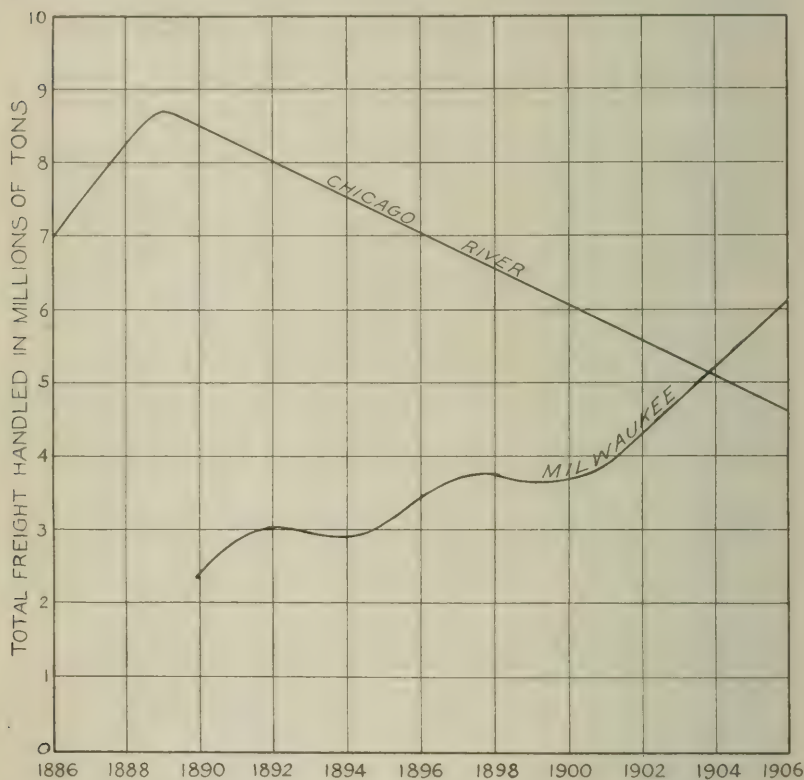


Fig. 2.—Comparison of Freight Tonnage of Chicago and Milwaukee.

There are two reasons why Chicago shipping has declined. One of these is a natural shifting and change of business, which could not be prevented, the other is due to artificial obstructions to navigation, which has made it both impossible and uneconomical for shipping to do business in the river. The advent of large ships in lake commerce and the beginning of the decline in volume of business in the Chicago river occurred at the same time. For reasons of economy large ships were built and they naturally, on account of lower operating costs, took

business away from small craft. Also these small ships gradually became old and went out of commission, so there was a continuing decrease in the number available. But as the large ships could not enter the river on account of narrow openings at the center pier bridges, shallow water due especially to the presence of the old LaSalle, Washington and Van Buren Street tunnels, as well as to narrow and crooked channels, these large craft necessarily went to other ports for business. It is impossible to determine what proportion of the loss is due to natural, and what to artificial causes. The principal kinds of freight, which have shown undoubtedly a decline in amount,

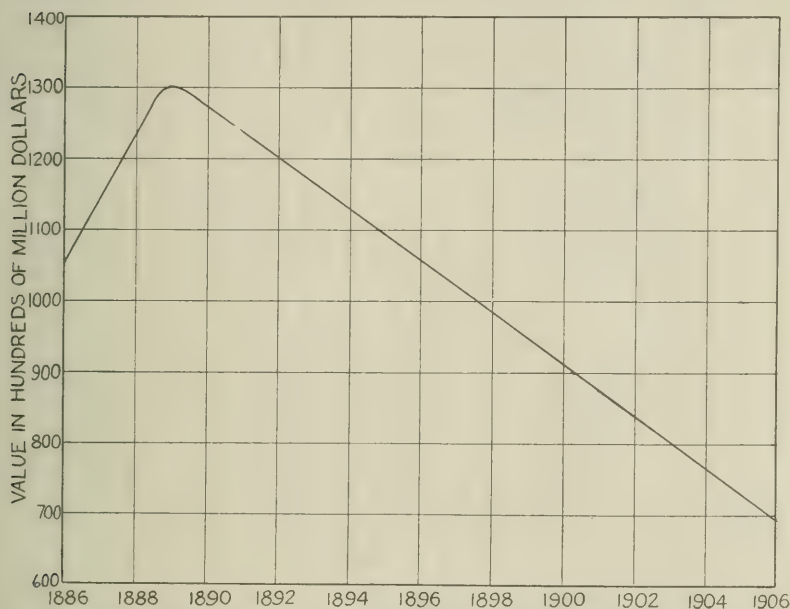


Fig. 3.—Value of Freight Handled at the Chicago River. Basis of \$150.00 Per Ton.

at the Chicago river are, lumber, coal, grain, and iron ore. The decline of lumber has been due very largely to natural cause. This is also true of coal, but in a less degree, the exploitation of home fields having reduced the market for foreign coal. With grain, it would appear that the cause has probably been entirely artificial. In this connection, Fig. 4, illustrates the production of grain in the states of Wisconsin, Nebraska, Kansas, Missouri, North Dakota, Minnesota, Illinois, Iowa and South Dakota, which the Chicago Board of Trade considers as the territory contributory to Chicago. This shows an increase in production during the last nine years. Fig. 5 shows an increase in the grain receipts at Chicago, from 1890 until 1908, and shows an increase in

1908 over that of 1890, of about 31%, which indicates that receipts at Chicago have kept pace with production. Fig. 6 illustrates the proportion of grain shipments from Chicago by rail and by lake. From 1890 to 1897, as compared with rail, lake shipments increased rapidly; this may be accounted for by the building of elevators on the Calumet river, which offered new and better facilities. The relations change rapidly after this time, owing to the loss at the Chicago river, which was so great as to more than overcome the gain at the Calumet River. So that at the present time 21% is shipped by lake and 79 by rail. All of the data employed in plotting the curves of

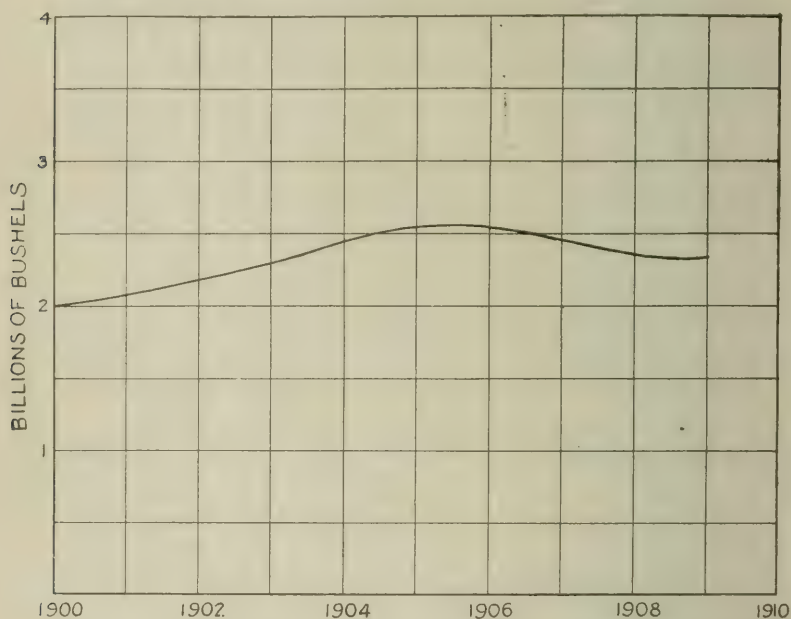


Fig. 4.—Production of Grain in Territory Contributory to Chicago Market.

Figs. 4, 5 and 6, were furnished by the Chicago Board of Trade. With iron ore the volume at the Chicago river dropped to zero many years ago, such small quantity as was received here since that time came by rail from Milwaukee, but the increase on the Calumet has grown rapidly, so the port of Chicago as a whole, has shown a very large gain. With grain, however, a traffic largely dependent upon direct connection with railway lines, the case has been quite different. The railway terminals are mostly at Chicago proper, but the accommodations for ships are on the Calumet.

Figures 1, 2 and 3, deal with volume and value of freight.

The situation, however, is better illustrated by Fig. 7, showing rate of increase and decrease in percentage of freight, as given in volume by Fig. 1. Chicago's actual position is, however, better illustrated by Fig. 8, which shows, for the period taken, that while Chicago's population has increased 42%, freight business at the port has declined 8.5%, and that of the Chicago river 28%. During this time Milwaukee has made a gain of 77%, and the growth of all lake shipments is 117%.

It was the presence of the Chicago River that determined the location of this city, so it may be said that the river is the

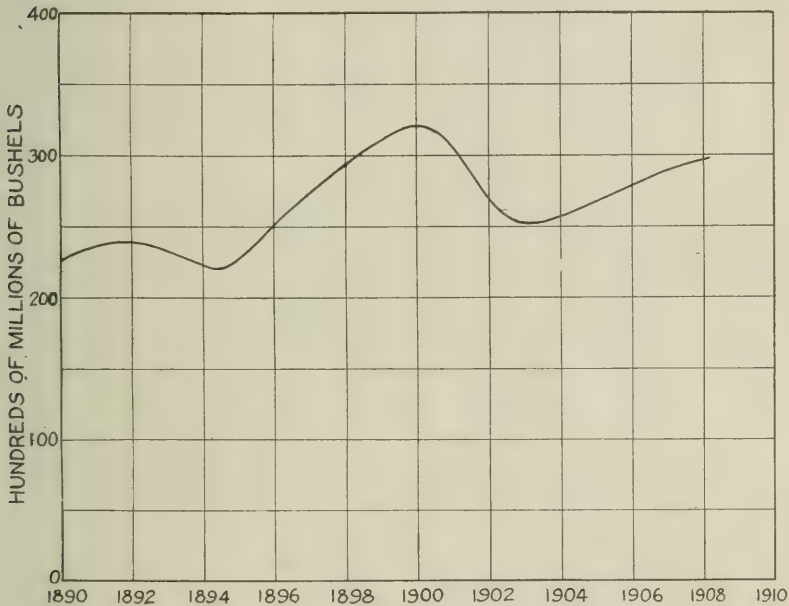


Fig. 5.—Grain Receipts at Chicago and South Chicago.

cause of its existence. Thus it has been of inestimable value. But as the city grew, bridges multiplied, which had to be frequently opened. So the river, which had formerly been a benefit, became also an obstacle to the growth of the city. But the general public thought only of the inconvenience and forgot the benefit. So in 1890, and thereabouts, the newspapers and public were discussing the "bridge nuisance." Today we have a reaction in public feeling and the "harbor problem" is an issue, although probably not as live a one as it should be.

At the present time, conditions on the Calumet are good, and the growth of business as illustrated by Fig 9, is quite satisfactory. As far as benefit to Chicago is concerned, the whole Calumet district from South Chicago to Gary may be considered

April, 1910

as a unit. Upon this basis an estimated extension of the curve has been made for the years from 1906 to 1910 to embrace the growth at Indiana Harbor and Gary. Here channels are wide and deep and there is but little obstruction to navigation. The Calumet locality has, therefore, an important future, which will later have attention.

The present problem is in the Chicago river, where facilities of every description for the proper and economical handling of business are inadequate and are such as to make further growth under the circumstances an impossibility. Other transportation features are involved than those of freight and passenger move-

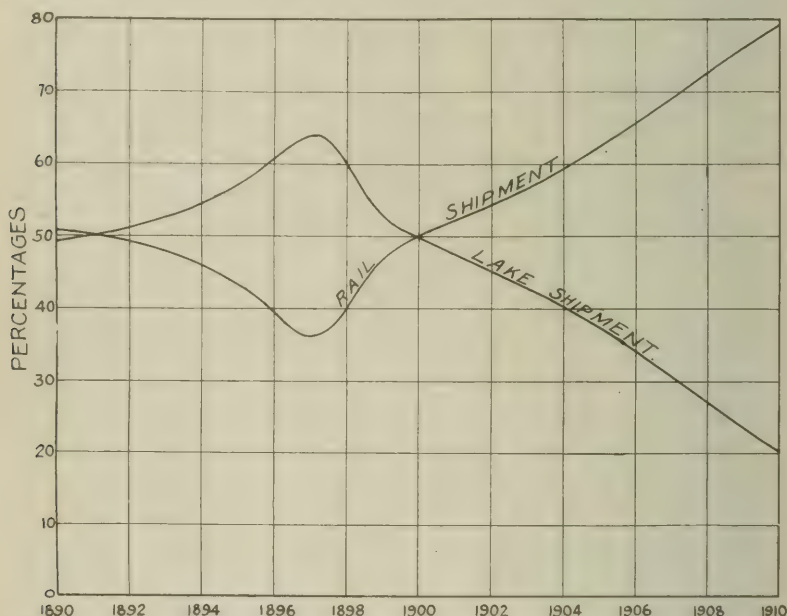


Fig. 6.—Shipments of Grain from Chicago and South Chicago by Lake and Rail—by Percentage.

ments upon the river. The problems of cartage by wagon, the handling of goods at railway freight houses, the transfer between railroads and the movement through the tubes of the Illinois Tunnel Co., are all interrelated with the river business so that the whole aggregation becomes a single problem of considerable magnitude and as such it appears there must be one general solution instead of several individual remedies.

It is necessary and desirable that the movement of craft that require the opening of bridges be reduced to a minimum. This requirement it would appear may be met by freight lighterage on the river and by outer harbor facilities for passengers and freight,

making it unnecessary for ships to enter the river having a cargo which may be received and distributed by lighters, by way of the

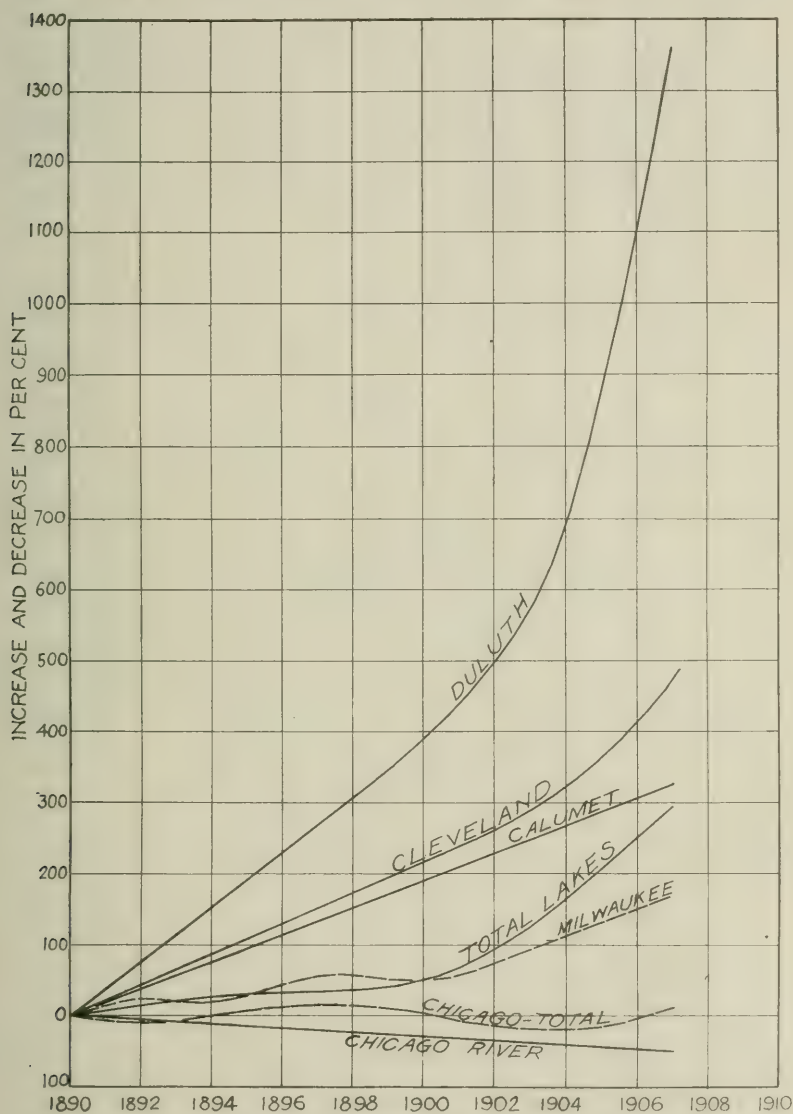


Fig. 7. Comparative Increase and Decrease of Commerce at Sundry Lake Ports.

tunnels, or directly to railway cars, which would be moved on car floats or track. This would keep at least all package freight and passenger steamers out of the river. Thus it would be possi-

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ble to have a large increase of coarse freight steamers in the river without it being necessary to open bridges any oftener than at present.

There is an enormous volume of miscellaneous freight, which is teamed about and through the city at a high cost, causing congestion of traffic in the streets and resulting in much inconvenience. A large portion of such goods could be handled by lighters on the river, which would then become one of the city's highways. These lighters would pass under the bridges and therefore would

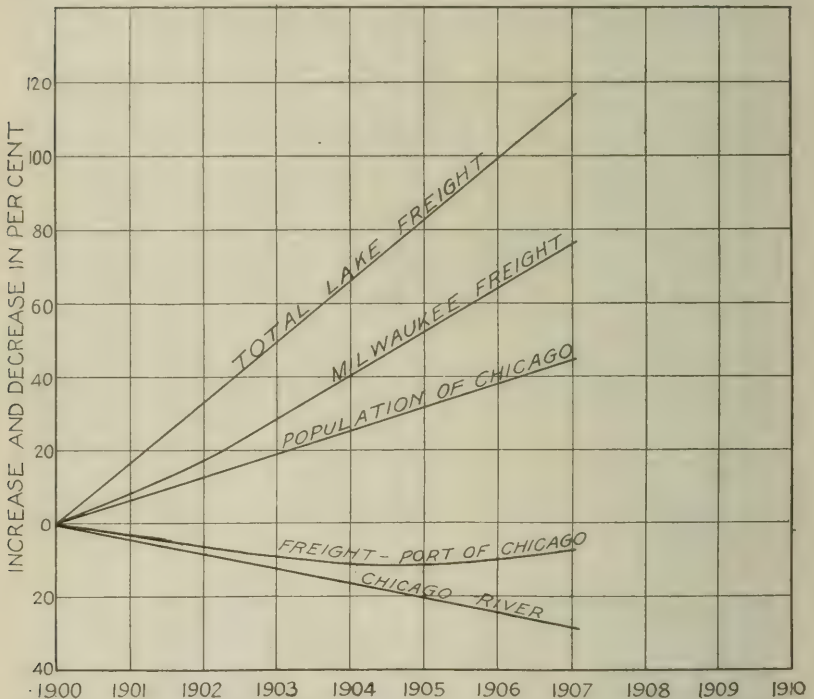


Fig. 8.—Decrease of Lake Commerce at Chicago Compared with General Development.

in no way interfere with traffic across them. Under present conditions, steamers carrying miscellaneous freight must pick up and discharge their cargoes at various docks along the river, which results in delay, inconvenience, large cost for service of tugs and frequent opening of bridges. All this trouble and extra expense would be eliminated by a proper lighterage service. These facts, as set forth in the report of the Harbor Commission, appear to be fully realized and there also seems to be a general feeling that the city should take some step toward the establishment of such facilities. But the legal limit to bond issues makes it impossible

for the city to raise money for the purpose and there appears to be no immediate prospect of its being able to do so. Two schemes, however, have been proposed, which contemplate doing for the city what the city is unable to do for itself. The first by private and the second by public enterprise.

The Pugh Terminal Company, a corporation conducting a warehouse business on the north pier, desires to establish a lighterage service on a large scale, also an outer harbor plant in the lake, just north of the river mouth. It has a grant from the State of Illinois and the Federal Government has stated that its plans do not interfere with navigation. While it appears probable that

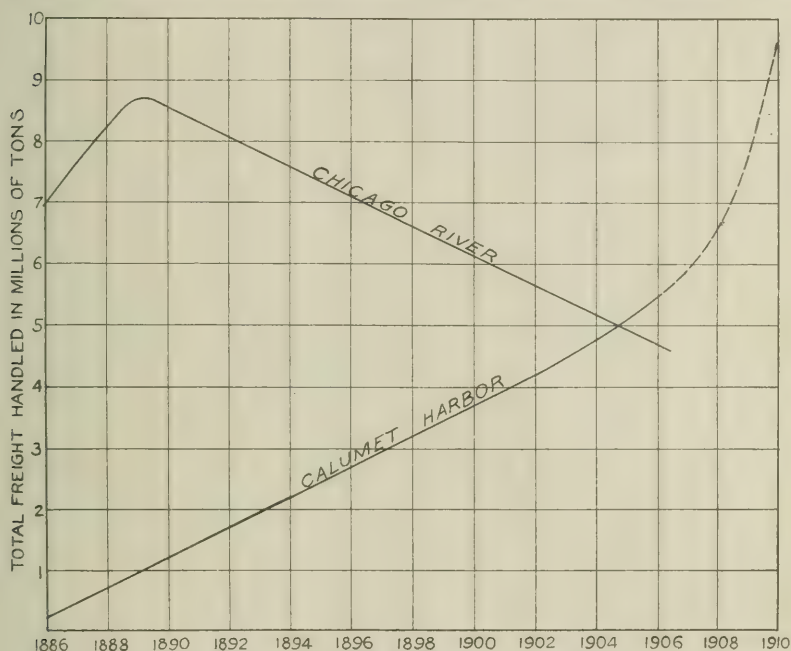


Fig. 9.—Comparison of Growth of the Calumet and Decline at Chicago River.

it has sufficient authority to enable it to proceed with its plans, the company states that it wishes the sanction of the city government and it now seeks a franchise from the City Council. Briefly, this scheme contemplates three long piers, one each for incoming and outgoing freight, the third for fruit and passenger business. The freight piers are to be equipped with railway tracks so that cars may run their full length. A refrigerating plant would be provided for fruit and other storage rooms. Adjacent to these docks a system of large warehouses would be built. A system of lighters would be established for the transport of not only loose freight, but of railway cars as well. These car floats would each be large

enough to transport from twelve to sixteen cars, and would have a movable deck, which could be depressed sufficiently to allow the tops of the cars to pass under bridges of all streets. These lighters would be propelled by internal combustion engines, so there would be no smoke nuisance. At convenient points on the river, freight stations would be provided for the receipt and distribution of freight to and from all railway and other docks, railway freight houses and business establishments. These docks would also be connected with the tubes of the Illinois Tunnel Company. Thus the scheme would embrace a very complete system of freight handling and storage. One of the benefits of a service such as this, which is probably not fully realized, is the removal of teams and wagons from the congested streets.

The second suggested scheme for harbor development, other than by the city, is that the Sanitary District take over the harbor management and carry out plans necessary for improvement. The reason for this suggestion, is that the Sanitary District, it is claimed, has power to raise money, which the city lacks. Thus, it could do for the city, what the city is unable to do for itself. A bill giving the necessary authority to the Sanitary District, is now before the State Legislature. At the time this bill was introduced another was presented, which originated in the Committee on Harbor, Wharves and Bridges of the City Council, which proposes to give the city the right to build and operate docks, wharves, lighters, etc. In asking these privileges the Council Committee has felt that, if granted, it would have a freer hand in dealing with the general harbor proposition, even if funds are not now available.

The ideal scheme would be to center on the Chicago river the business which could be handled by lighters. All the coarse and large cargo freight would be at South Chicago, but there is a considerable business on the Chicago river, such as lumber, grain and coal, and more is to be had, if the center pier bridges are removed. If it is to be had at all, it must be accommodated on the river, because it is needed either for consumption or reshipment at this point and not at South Chicago. Another phase of this matter is that ships select cargo to a port which can furnish return freight; we should be able, for example, to furnish a steamer, which may have brought anthracite coal, for use here, with a return cargo of grain. While it is very desirable to develop a lighterage service to its maximum possibilities, it is not good business policy to drive away desirable traffic, which must be carried by ships that are required to enter the river. Yet it is desirable to reduce to a minimum the necessity for ships entering the river and to this end it may be feasible to handle a portion of the grain traffic in cars by lighters direct from rails to ship, in an outer harbor, as well as through storage elevators located at an outer harbor.

While under present conditions the Chicago river is the center of the high class package business, and the Calumet, that of coarse freight, conditions will change at the latter, for the Calumet locality is growing rapidly. So in a few years the Calumet River will find itself confronted with just such conditions as did the Chicago river in the past and it is essential that the mistakes here be not repeated at South Chicago. In this connection, it is well to realize that Chicago will soon have two congested centers, one on the Chicago river, the other at the Calumet river. The public are no doubt disposed to feel regarding the Calumet as did the people here 25 and 30 years ago—that the Chicago river would take care of itself, but if development there is not properly cared for, there will be a repetition of the errors that have cost so much at the Chicago river.

The Harbor Commission's recommendation concerning bridges, is for a clear channel way of 200 feet. Among other bodies, however, which have given the matter attention, there is a diversity of opinion. Some believe that 140 feet is sufficient, others that 200 feet is preferable, but would be satisfied with 140 feet, in view of the difficulty in securing funds required for larger spans. There are also others who claim that in all cases, a 200 foot channel is beyond the limit of practicable design for bascule bridges.†

The committee is strongly of the opinion that the outer harbor facilities should be developed and utilized to the maximum, to so far as practicable keep large shipping out of the rivers and this applies to the Calumet as well as the Chicago river. It does not, however, favor the exclusion of necessary traffic, therefrom, which can not otherwise be accommodated. For this there are two reasons, one the avoidance of bridge openings, the other the saving in time and expense to shipping. Thus, considering the great value and convenience of outer harbor facilities, it is felt that ample reservation should be made on the water front for any possible future requirements, whether this would interfere with the Chicago Plan, or schemes for park development or not and that if it does, such plans should be changed to meet harbor requirements.

The duty of the City in reference to harbor development is a matter which does not appear to present itself very clearly. That the replacement of bridges and the straightening and widening of the channel of the river should be done by the city is without question. But the municipal operation of docks and lighterage service, in the opinion of the committee, would not be in accordance with good policy. It is not certain that it would be neces-

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† In this connection, see the discussion by Mr. C. R. Dart, M. W. S. E., of the paper entitled THE CHICAGO HARBOR, by John M. Ewen, M. W. S. E. *Journal Western Society of Engineers*, Vol. XIV, Page 763.

sary or desirable for the municipality to construct and own docks, to be leased to others, if private enterprise could be depended upon to do so, but, it would be necessary for the city to exercise proper control over such harbor facilities as would be developed by such private enterprise. This, it is felt would be the logical solution.

In conclusion of this first report, the committee feels that it should, in general, endorse the recommendations of the Chicago Harbor Commission, which under the chairmanship of Mr. John M. Ewen, has so fully reported on the problem.

January 18th, 1910.

#### DISCUSSION.

*President Alvord:* It is always desirable for the engineering profession to maintain what is called an open mind on any important problem, and nothing perhaps illustrates the advantage and the necessity of the open mind more than a proposition like this harbor problem. Until we had this problem carefully studied we did not realize, I think, what a complexity of influences were working. The very admirable studies which have been made by the Harbor Commission and various experts who have from time to time lately given us new light on this subject, have made us feel that there is much more to the problem than we have ever realized. I think the committee is to be greatly commended for having gathered together in brief and concise form so much of this valuable study that has been lately made, giving us the advantage of having it before us.

The meeting is open for discussion. There are quite a number of gentlemen with us this evening who are interested in the harbor question, and I am sure we shall be glad to hear from any one who can throw further light on this question.

*Col. C. McD. Townsend, M. W. S. E.:* I am a stranger to some of you, but I am in charge of the improvement of the harbors of the waterways connecting the great lakes, and am vitally interested in this matter as an incident to my work. I have also been on a number of Boards that have had charge of the question of the deep waterway from Chicago to the Gulf and have had to submit a report on that matter, so I am somewhat familiar with the conditions that exist here at Chicago.

I read this paper with considerable interest and found that I had a great deal of supplementary data, which I will present to you.

When the majority of the wharves and slips were constructed on the Chicago River, there were few if any vessels on the Great Lakes over 200 feet in length, and 12 feet draft; but the construction of the locks at Sault Ste. Marie and the deepening of the channels connecting the Great Lakes have created a

revolution in vessel construction. In 1890 a vessel was built 310 feet in length, by 1895 the length had increased to 380 feet, by 1900, 474 feet, by 1905, 569 feet, in 1906, over 600 feet; and I am informed by a representative of the Pittsburgh Steamship Company that at the present time there are built and contracted for 19 vessels of 600 feet in length, capable of carrying a cargo of 12,000 tons each.

In 1895 the freight passing the "Soo" was all in vessels less than 400 feet in length; in 1903, 40 per cent of the freight was carried in vessels exceeding that length; and in 1908, 74 per cent—45 per cent being in vessels over 500 feet long. This has resulted not only from the building of large vessels, but also the withdrawal of the smaller from trade. In 1895, 877 vessels were locked through the Weitzel Lock with a total of 16,793 passages. In 1908, the vessels of the same class passing the Soo were less than 400, while the total number of passages of all vessels was 15,181. In 1895 the average ore cargo was 1,800 tons; in 1908, over 8,000 tons.

A vessel 200 feet long has comparatively little difficulty in navigating the Chicago River, even in a moderate current; but when three-fourths of the commerce of the lakes is in vessels exceeding 400 feet in length, it is another story. With a discharge of 10,000 cubic feet in the Chicago River, it will be a physical impossibility for a modern lake freighter to proceed from the mouth of the river to the Chicago Drainage Canal, or to enter any of the numerous slips in its vicinity. In my opinion, the widening and deepening of the Chicago River to more than 16 feet above the Forks for purposes of navigation is a waste of public funds. If Chicago River is ever to regain its commercial importance, it will have to be by a system of wharves near the river mouth and distribution of freight by lighters.

The value of barge navigation is not appreciated in this country as it should be. The lighter is one of the great causes of New York's supremacy in the United States. According to the census report for 1906, there was a traffic by water in New York Harbor of over 113,000,000 tons, of which about 33,000,000 tons was in the coast trade, 25,000,000 tons in foreign trade, and 55,000,000 tons a harbor traffic—i. e., there was a barge and lighter traffic far in excess of the combined rail and water commerce of Chicago.

In the very able paper on the "Development of Commercial Ports," in the report of the Chicago Harbor Commission, I regret that a more detailed description of Cuxhaven, the auxiliary port to Hamburg, was not given. Hamburg had to face a somewhat similar problem to that which confronts Chicago at the present day. The enormous increase in draft in the transatlantic steamship had to be met, and that city's solution of the problem was an outer harbor, and the lighter.

While New York is more favorably located for the use of lighters, due to the enormous development of shore line around New York Bay, Chicago is naturally in a better position than Hamburg. While Hamburg has five miles of river front, the Chicago River and its branches have already been improved for  $13\frac{1}{2}$  miles, and penetrate the existing business portion of the city as effectively as the railroads, while the Chicago Drainage Canal adds a large water front for business expansion.

If Chicago had not rejected the proposals of the officers of the Corps of Engineers during the past twenty years, she would today be connected to her hinterland by a far more effective waterway than connects either Hamburg or Rotterdam to Germany.

A deep waterway through a city does not necessarily add to its prosperity. Cities are created where deep waterways stop, and where the cargoes from the vessel are transferred to other means of transportation. The 60,000,000 tons of freight which passes Detroit annually does not benefit that city, but it passes through the Detroit River without seriously disturbing the traffic within the city limits. A ship canal through the heart of Chicago, ending at Joliet or Grafton, might be a very good thing for Joliet or Grafton but would simply be an insufferable nuisance to the city of Chicago and of little value in its commercial development. To pay for the construction of a ship canal, it must transport a considerable amount of freight. If we assume that a ship canal through Chicago would develop the freight that existed at the Soo in 1895, before the completion of the Canadian and Poe Locks, there would be required to carry that freight 16,793 vessels during a season of navigation, or one vessel would pass through Chicago, on an average, every 20 minutes. What would happen to the enormous land traffic across its 26 bridges under such conditions?

*Dr. Richard Price Morgan*, M. W. S. E. (by letter): I have read, with absorbing interest, the paper of the Committee on the Chicago Harbor Problem. To my mind it is lucid and fairly comprehensive, and I believe it will be a valuable factor in deciding the question. I desire especially to concur with the statement which very significantly discloses the present and ultimate coalescence of the vast manufacturing and business interests south of the Chicago River.

I also concur with the expression which, with equal significance, sets aside esthetics for commercial supremacy.

*Mr. John M. Ewen*, M. W. S. E.: The working out of what may be called the political or governmental aspects of public improvement problems ordinarily takes more time than the engineering features, however difficult they may be. Chicago spent over ten years in trying to solve the traction franchise problem. The rehabilitation of the street railway system, involving the ex-

penditure of many millions of dollars, is being carried out in less than one-third of that time.

Chicago needs better dockage facilities. There is substantial agreement that new docks should be built north of the mouth of the Chicago River. Engineers, if directed to undertake the work, could have the new docks in readiness for use within eighteen months of the time of starting. More than two years have already elapsed since the creation of the Harbor Commission, yet no one can predict at this time when the actual work of dock development for Chicago is likely to be undertaken. It seems to me that a progressive community ought to be able to work out the governmental aspects of these problems better than we have been doing in Chicago. The city is being injured by the delay in starting such a needed public improvement as the one under discussion.

The Harbor Commission in its report submitted to the City Council March 1, 1909, recommended construction by the city of piers north of the mouth of the Chicago River for the accommodation of passenger and package freight and the fruit lines. It further recommended the enactment of enabling legislation necessary to promote that end.

When the Council Committee on Harbors, Wharves and Bridges began to consider the subject, it arrived at the conclusion that the city's financial situation was not such as to warrant it in undertaking the work of dock development on the basis of immediate municipal ownership. Therefore the committee entered into negotiations with promoters looking to dock development under a franchise arrangement. I am not necessarily opposed to a franchise plan, but it does seem to me that the negotiations with the Pugh interests are not likely to lead anywhere. No other serious competitor for a dock franchise grant has thus far appeared upon the scene. There appears to be little likelihood, therefore, of the early starting of a dock enterprise through city activity, either on the basis of city construction and ownership or under a franchise arrangement.

In view of this situation the practical thing to do, it seemed to me, was to make the Sanitary District Board the harbor authority for Chicago and give it the power to go ahead with the work of dock development. This course, provided the necessary enabling legislation can be secured, means speedy action as opposed to a long period of delay and inactivity if the city is to be made the agency for dock development. The Sanitary District has at its disposal the funds necessary for undertaking and carrying on the work. It has a good business and engineering organization. The Sanitary District as a harbor authority would correspond somewhat to the harbor trusts which have control of harbor and dock development in the principal cities of Great Britain.

Briefly stated, the foregoing are my reasons for favoring legislation authorizing the Sanitary District to undertake the work of dock development for Chicago. I believe that after full consideration of the subject this view will be accepted as sound by the city authorities as well as by the public at large.

*Mr. Isham Randolph, M. W. S. E. (by letter):* I have read with interest and profit the report of our committee, and express my belief that Messrs. Bement, Abbott, Ritter, Shankland, and Smith have rolled up a wad of wisdom in the sentence on the last page, which reads:

"Thus, considering the great value and convenience of outer harbor facilities, it is felt that ample reservation should be made on the water front for any possible future requirements, whether this would interfere with the Chicago plan, or schemes for park development or not, and that if it does, such plans should be changed to meet harbor requirements."

My own views were concisely expressed for the use of our chief state executive in the following statement:

Chicago needs a harbor.

Chicago is losing its share of the water-borne commerce because it has no adequate harbor.

Chicago has no money now, or yet in definite prospect, with which to build a harbor.

Private interests know this, and are tempting the city officials to turn over to them its rights in waters and submerged lands to it belonging or by it controlled.

Chicago has bartered her commercial birthright for visions of beauty in which parks, shrubbery, lagoons, drives, pagodas, triumphal arches, and all the rest of the gorgeous pageant usurp the waters in which ships should lay alongside wharves and warehouses equipped with every modern convenience for interchange of freight with cars on contiguous tracks; which tracks are there for use upon equal terms by every road entering the city.

Chicago needs a harbor for the lake freighters that are plying, and for the river boats that will ply between her port and New Orleans when the lakes-to-the-gulf waterway is an accomplished fact.

There is a way open for Chicago to get a harbor which will be her own, and cramped by no private interest, and that the best harbor on the lakes. What is that way?

First, repeal the act which robbed commerce of its right and gave all of the lake front to the Park Commissions. Then, if you will, pass a new bill which will give the South Park Commission all of the lake front between Forty-second street and the Indiana state line which does not belong to individuals or corporations. Let commerce have one-seventh of Chicago's

water front. This done, impose upon the Sanitary District of Chicago the duty of creating a harbor for Chicago; such a harbor as the second greatest city in America ought to have.

But why impose this duty upon the Sanitary District of Chicago? Because that district is a creation of the state, and the state may and can enlarge the scope of its duties. Because that district has taxing powers which do not have to be enlarged to enable it to carry on the work of harbor building. Because the limit of bonded indebtedness of that district has not been reached; therefore, because the Sanitary District of Chicago has the financial ability to plan, prosecute and complete the work. Because the Sanitary District is officered by citizens of Chicago whose interests are bound up in the welfare of the city. Because the trustees of the Sanitary District have an enviable record for honest administration and successful accomplishment.

Because Chicago needs its harbor at the earliest date that it can be created, and the Sanitary District is a going concern, fully officered and equipped for conducting and accomplishing large public works.

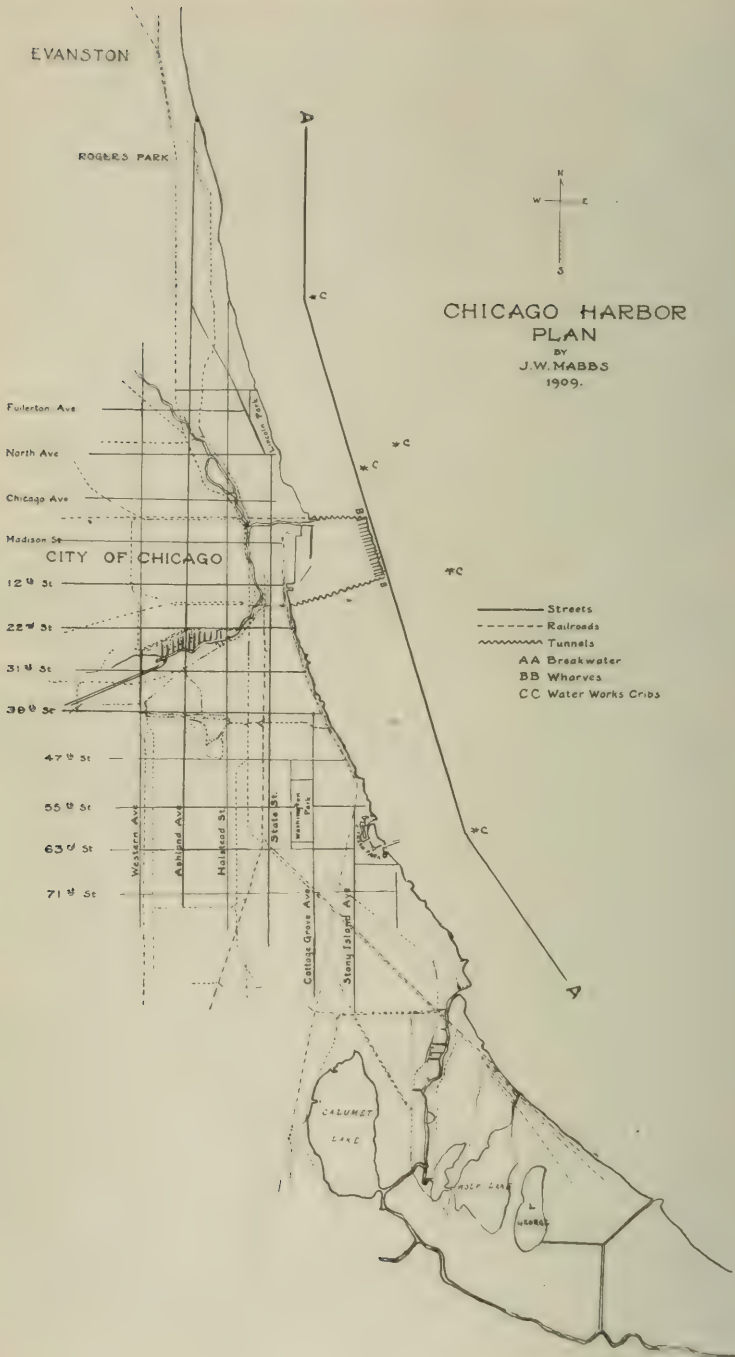
Because, if the day comes when a wise public policy demands a transfer of authority from the organization known as the Sanitary District of Chicago, to the organization known as the City of Chicago, there will be no vested private or corporate rights to intervene and prevent the transfer.

*Mr. J. W. Mabbs, M. W. S. E.:* This subject is of great interest to me and is one to which I have given a good deal of thought for a number of years. I have a plan, shown on the accompanying map, which may be of interest to the members.

In the first place I wish to say that I heartily endorse the report. The plan that I wish to present I think fits in very nicely and will fulfill all the requirements for a harbor that have been set forth.

Chicago, I think, is destined to become the metropolis of this country, and when it does it will undoubtedly be the metropolis of the world, and it is eminently fitting that Chicago should have a harbor that will be in proportion to her future greatness. In order to secure this, it becomes necessary to have a comprehensive plan, great enough and flexible enough to take care of her future requirements for all time. The report mentions a plan of building wharves at the mouth of the river. This would not produce a harbor but would merely increase the wharf facilities. The plan I wish to present is as follows:

The line AA represents a breakwater or sea wall, from a point near Evanston south to beyond the Calumet River. This sea wall can be made from the broken rock that now lies on the banks of the drainage canal, there being a sufficient amount to build a wall of this description the entire length of the city, some twenty-five miles or more, and this rock can be taken there



by water transportation and dumped until it comes within a very short distance of the surface of the water, when dump cars can be used to complete it. This can be done at an expense very little above that of building a railroad embankment, variously estimated to cost from twenty-five to thirty and thirty-five cents a cubic yard. Figuring this embankment at fifty cents a cubic yard, which should be ample for all contingencies, a sea wall or breakwater could be built twenty-one and a half miles along the lake shore of this city for about six or eight million dollars. Of course this does not include any wharves or any connecting tunnels, which undoubtedly would be an expensive part of the proposition.

There are a number of features that do not appear at first glance in connection with this harbor plan. They are strictly of a sanitary nature and for this reason should come under the jurisdiction of the Sanitary District.

Such breakwater may be built a quarter of a mile inside of the waterworks cribs. This would protect our drinking water from all contamination from the city, as well as at times of freshets, when flood waters pass out of the Chicago and Calumet Rivers. If this harbor were built, the flood would pass into an immense basin, which would act as a reservoir and take care of the flood water until such time as the current reverses, when it would all be carried gradually back down the canal again. This would take care of a feature that the drainage system has not been able to provide for, and which is a very important item in connection with the city's health.

One reason for suggesting the location of the breakwater so far from shore is to influence the approval of the park boards. They are anxious to beautify the city, and by locating the harbor and breakwater so far from shore the park boards could carry out their present plans of beautifying the city by constructing boulevards along the Lake Front, and at the same time the city would have a magnificent harbor that would be capable of taking care of its wants for all time to come.

After such breakwater would be built from a point near Evanston to the Calumet locality, a distance of twenty-one and one-half miles, slips or wharves could be located on its shore side. Such slips could be about a quarter of a mile long, which would be ample for any lake craft. These wharves and slips could be connected to the shore by means of tunnels; for example, one with the railroad terminals north of the river, and another with the Sixteenth street system of railroads; these tunnels to be connected by a longitudinal tunnel, from which the cars could be lifted to the wharves by means of elevators, so that the freight could be transferred directly from the railroad system to the shipping, and vice versa. It would also become necessary, no doubt, to have grain elevators and coal trans-

fer arrangements on these wharves, so that coal and grain could be quickly handled. At the north end of the breakwater there would be a large opening to the harbor, so that shipping coming down the lake in times of storm could make this harbor without any difficulty, and pass down inside of the breakwater in safety to the wharves. This breakwater could be built in sections as funds permit and circumstances demand.

As I said before, Chicago needs not only wharves but a harbor, and this plan would provide a harbor that would be second to none in this or in any other country. As the city grows, these wharves could be extended along the breakwater to a point opposite the Thirty-ninth street system of railroads, or beyond, and another system of tunnels from the breakwater to Thirty-ninth street would give additional railroad connection; at the same time the harbor and wharf facilities would be increased to an unlimited extent.

As stated, the harbor proposition is only one part of the question. The Chicago subways and railroad communications is another important part of the general harbor problem. The plan that I present is only part of a plan of subways and tunnels that I think Chicago will need some day, and, in fact, needs already. My idea is that subways should be of more than one story in height, and that there should be at least two and possibly three systems of subways. The upper system could be directly below the street level for local and possibly express passenger traffic. Below this level an express system could be established if necessary. The time might never arrive, however, when it would be necessary to put in an express system lower than the first level, as express and local systems could probably be run in unison except at crossings (I think subways of this city should have no grade crossings), where I think they should be on a different level. Below the passenger subway I suggest a system of freight subways to form a connection with the outer harbor. In my opinion the Illinois tunnel as it exists today is one of the most unfortunate obstacles in the way of a proper system of subways that confronts the city. It is too small to accommodate freight traffic and it is in a position that interferes with a system that would meet the city's requirements. It seems to me that the subways of this city will never be what they ought to be until the Illinois system has been practically wiped out of existence or very much enlarged. As has already been stated, the harbor and wharves form only a part of the plan necessary to properly handle the constantly increasing freight traffic of this great city. There must be a system of subways connecting wharves with the railroad terminals that will be capable of almost indefinite enlargement.

Chicago is already the greatest railroad center of the world and will undoubtedly continue to be for some time to come. Not

many years ago it had the proud distinction of having the greatest amount of marine traffic of any city in the world; less than twenty years ago the tonnage of the shipping of Chicago was greater than the tonnage of Liverpool and London combined. So it seems to me that there is no reason why Chicago should not regain her lost supremacy and be the first maritime city in this country, if not in the world.

*President Alvord:* What is the depth of water at the location of your proposed breakwater?

*Mr. Mabbs:* The depth is from thirty-five to forty feet and the breakwater would require a stone embankment about forty feet high on the average. Undoubtedly the embankment would have to be about 135 or 140 feet wide on the bottom with a very gradual slope towards the sea, and should be nearly perpendicular on the inside, especially at the wharves, as in that location there would be heavy concrete retaining walls from the bottom of the tunnel to the top of the wharves, and the rock breakwater would have a gradual slope from these walls toward the sea.

*President Alvord:* Would this breakwater bear a general resemblance to the outer breakwater at Buffalo?

*Mr. Mabbs:* I am not familiar with the Buffalo breakwater.

*Mr. H. B. Ford:* I would like to ask if Mr. Mabbs has made any estimate of the cost of freight and passenger connections with his proposed piers?

*Mr. Mabbs:* The connections would be an expensive part of the plan.

*Mr. Ford:* I would like to ask Mr. Mabbs if the cost would not be prohibitive?

*Mr. Mabbs:* I do not think so. At first it would not be necessary to put in more than one system of tunnels. There are several ways of doing this, so that the expense of building two miles of tunnels would not in any way be prohibitive.

*Mr. R. J. Mershon, M. W. S. E.:* I would like to ask Mr. Mabbs who would bear the expense, the state or the general government?

*Mr. Mabbs:* It has been stated that the Drainage Board has the power and the taxing ability to do this work, and I think it could be done at a cost not to exceed that of schemes that have already been advanced for Chicago harbor development. Undoubtedly the United States government would give substantial assistance.

*Mr. Mershon:* Then I would like to ask Mr. Mabbs if these auxiliary improvements, railroads, etc., would not cost five or six times more?

*Mr. Mabbs:* They might cost several times as much as the breakwater.

*Mr. Mershon:* I would ask Mr. Mabbs if fifty million dollars would cover the cost?

*Mr. Mabbs:* That would depend upon how much of the breakwater was built, and how many tunnels were put in at one time. I estimate that a large portion of the breakwater, one system of tunnels, and sufficient wharves for Chicago's present needs could be built for \$10,000,000, and not over one-half of this amount would have to be expended before the city would begin to reap the benefit. The plan could be extended and enlarged from time to time to such an extent that in a hundred years the expenditure might reach \$200,000,000.

*Mr. Mershon:* I am not very well informed on this harbor question, not having given much attention to it, but it seems to me that if the same amount of money were used to construct an estuary somewhere between Sixteenth and Twenty-fifth streets, two hundred feet wide and tangent to the bend in the south fork of the Chicago River, an inland harbor might be constructed that would be a great deal better than any lake front harbor.

The Chicago and Calumet Rivers are the natural places for harbors, and Chicago has grown to promote that end and condition and the condition should not be changed. An estuary tangent to the bend in the south fork of the river near Twelfth, Sixteenth or Twenty-fifth streets, or thereabout, leading out to the lake, is, I think, the best solution of the whole question, but by no means should there be any lake front harbor at the mouth of the river, or anywhere else along the lake front. The channel 200 feet wide should give the largest boats egress and ingress above Van Buren street, and all along the south fork and drainage canal is the proper and ideal place for docks for receiving and handling freight under all conditions between water and rail. This is an age of competition in freight handling and an age of intense railroading, and if Chicago maintains supremacy over other ports as a shipping point, and holds it, there must be attractions for commerce. Lighterage and tug expenses must be largely eliminated; time is not usually so important with boats that they are willing to spend \$200 or \$300 for tug or lighterage service.

Vessels and railroads must receive and transfer freight in one handling, and with the best modern equipment. If in the future Chicago reaches the magnitude predicted by some of her captains of industry, or one-half of it, and is to be the greatest city in North America as predicted by Baron Rothschild, the Chicago drainage canal will be needed for docks, warehouses, and commercial interests. If Chicago proper wishes to hold her own as against the Calumet district, which will be able to take care of itself by natural advantages, there must be no botching of the lake front harbors at the expense of river improvements.

and the work should be done in the proper, natural, and most convenient places.

An estuary (as Mr. L. E. Cooley has pointed out) on the South Side, where boats can pass in and out through clean water, will, to my way of thinking, be the proper solution of the question. The cost will very likely be not more than other plans suggested, and possibly less.

Eventually great changes will doubtless be made in this district by railroads and terminals, and great subways are needed. An estuary 200 feet wide, nicely walled in for the few blocks with no docks, would not be unsightly. Besides, strenuous efforts should be made to build the city to the west and not so much along the lake front. The river and drainage canal are the advantageous points and should be utilized to the utmost. We already have these channels that have been procured at great expense, and to build harbors elsewhere is to abandon the former project and add millions more to the cost.

Past experience chose the river as the best harbor; change the method and you make conditions worse and destroy the city's scenic beauty.

*Mr. Geo. E. Hooker, Civic Secretary, City Club, Chicago:* Naturally I have been much interested in the presentation of this subject. There are two things which impress me. The first is that so far as I have learned, the results of investigations have not tended to answer the question as to how the connection between land carriage and water carriage can actually be worked out; that is, how the railroad and the dock are to be united. The proposition has been made that there should be a tunnel connection, and the Commercial Club report suggests that there should be a subway connection between the railroads and two proposed harbors, one near the mouth of the Chicago River and the other at the Calumet River. As to how that is to be accomplished—how the various railroads would be managed so as not to withdraw them from reasonable accessibility to business, so as not to interfere with the organic unit of the central portion of the city as a business organism, and so as to keep within reasonable limits of expense—those matters have not, I think, been gone into.

The more I hear this subject discussed, the more am I impressed with the meagerness of the scientific attention which it has thus far received. I was interested a moment ago to hear an engineer connected with this society express his opinion, after some years of observation, of the Illinois tunnels. Although not a technical man, I urged, when that project was before the city authorities, that no development of that sort should be authorized without a very careful and comprehensive study of the whole question. I have heard opinions expressed by financiers or engineers in other places, agreeing more or less

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definitely with the opinion so expressed by this member, that the project was not properly studied before it was undertaken. The question of a harbor is certainly not less important than the tunnel question, but our Harbor Commission has merely had the assistance for a brief period of two or three experts in its investigations, and has spent perhaps five or ten thousand dollars.

The construction of a harbor and docks, as Mr. Mabbs has indicated, must involve very large expenditures. The cities that we have had quoted to us from the other side of the ocean have harbor budgets running over many years, which total anywhere from forty to one hundred million dollars or more, and the amount of scientific inquiry that has thus far been bestowed upon this question by us becomes almost trivial in comparison with its importance. Yet we are at the point today where in certain quarters it is possibly expected that we are going to drive the first stake in regard to this whole development. I feel as though we were not prepared to tell where the first stake ought to be driven at the present time, and that it is of the utmost importance that the best technical skill that can be obtained should be brought to bear upon this question; also that we should hold things in abeyance until the thing can be passed upon much more completely and on a much broader basis of study and information than has yet been proposed.

*Mr. Ford:* I am not an engineer, but an agent of a lake steamer line. The rail trunk lines own the regular lake steamer lines and send package freight west from Lake Erie. These lake lines bring here about one and a quarter million tons of freight in a season of navigation. That all comes here and goes into consumption at less than the all-rail rate, and I consider that we should do something to restore, as far as possible, the missing commerce that was formerly in this port. If we are handicapped much more by city ordinances and one thing and another, the lake lines may be driven out of the port, and then we will be at the mercy of the railroads and we know what that is. The time has arrived when the owners and managers of vessels are doing the same as one does in his business, trying to handle them in the most economical manner. In other words, they are sending their boats where the line of least resistance exists. Today, Milwaukee has a better harbor than Chicago. The wild boat, the non-line boat, or, as it is commonly spoken of, the tramp boat, that carries ore, grain, and coal, will be chartered for a cargo of coal to Milwaukee in preference to Chicago, everything else being equal, because the boat can deliver the cargo there and get away more economically than she can here. Do not lose sight of this fact, gentlemen, as you are called upon to furnish a harbor, that the modern steamer costs from six to eight

dollars an hour to operate after she is put in commission. That makes about \$196 a day for twenty-four hours, and the only way she can offset this cost is by running and earning money. Therefore, if a boat comes to Chicago with a cargo of coal and is twenty-four hours here getting rid of it, she is out \$200. You will naturally see that the owner will not send the boat here again if he can possibly get a cargo anywhere else.

Now we are asked to have a harbor furnished. The most desirable point in Chicago from a marine man's standpoint—I know, because I talk with them all—is just north of the river, at the entrance to our harbor, and arrangements are about completed, I hope, to make a harbor there. As I understand it, Chairman Foell, of the Committee on Harbors, Wharves and Bridges, has about drawn up an ordinance. If we undertake to put the harbor at any other point on the lake front it will result, I think, in more delay and procrastination, judging from past experience. There is a car line already connected with the location of these contemplated wharves to carry passengers. Freight will be taken care of either over the C. & N. W. R. R. or by a system of car ferries. That is assured. It is a well-known fact and admitted by our municipal authorities, that the city has not sufficient money to carry out the scheme, but it may be ready to give permission to some other body to build the harbor. It may be the Drainage Board or a private corporation. But if any one has had any experience with a municipality or drainage board, or any other organization where legislation has to be had before anything permanent can be done, he can very readily see that there will be a great deal of delay. I will just cite the incident of the accident to Madison street bridge about Thanksgiving time. That bridge was out of commission a little over two months, and I think most any one will agree with me when I make the statement that if the bridge had been controlled by private parties, with one-half of the works on this side of the river and one-half on the west side of the river, the repairs would have been made in much less time.

*Mr. Andrews Allen, M. W. S. E.:* It is a fact that water transportation at Chicago is a very much more important factor than many of us realize. We are naturally impressed with the speed of railroad transportation when we see a freight train go by, but we do not always realize how many cars of important freight are shunted off onto some siding and left until they are dug out. We do know, however, that freight from Milwaukee and from ports across the lake is handled much more rapidly, economically, and satisfactorily to all concerned by water than in any other way. We are always thankful when navigation opens and we can send freight promptly across the lake, and not have to send it around the lake by rail, with the chances of having it lost at every siding that the train passes.

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The harbor question appeals to me in this way: We are all of us interested in Chicago. It is the metropolis of the West, the place where we live and the place where we do business. We are interested in its growth and in its prosperity, and know that the growth of a city and its prosperity depend on the facilities that we provide. We know, at the same time, that if we spend too much time in deciding what to do, the traffic will have changed to other ports and it will be a losing fight to regain it. I fully believe that we ought to give these questions thorough consideration, but we must not procrastinate. We have procrastinated for the last twenty years and the result is shown very eloquently on the chart which Mr. Bement has presented. Some of the plans that have been suggested this evening simply make the engineers' heads swim. We must remember that there are limits to our means; that we must begin where our work will be useful in a short time, and that we must spend with a view to improving our facilities on some general scheme, but we must plan for immediate improvement. It seems to me that the harbor north of the river will relieve the present conditions to a very great extent. This will provide at least for the package lines and for communication between the docks and the railroads, and will be a great improvement in itself. A lighterage system can also be installed with a small expenditure, and can be increased as the river facilities are improved. Developments can be carried on one step after another, forming a part of the general scheme, and the population and prosperity of a city will grow as facilities are provided. I believe thoroughly that if we should spend one hundred million dollars in improving the Chicago harbor and the deep waterway to the south, it would be but a very few years before the population of Chicago would be doubled. People will come here, not because they have to come, as do a great many of them now, but because they want to come; because the facilities are better than they can get anywhere else. That is the condition that promotes the growth of a city. The first requisite, of course, is to have the opinions of those commercial interests which use Chicago as a harbor and as a railroad terminal. Then comes the province of the engineer, to take these requirements and work them into a plan for improvement. We must have the data first; then the engineer may solve the problem. We should start, however, so that we will get immediate results.

*Mr. Mershon:* It seems to me that if Chicago is to keep on growing as has been predicted, it will grow over too far into Indiana and after a while it will extend to Michigan City, as well as along the North Shore. It seems to me something should be done to spread the city to the west, down the drainage canal to Joliet, and keep it more compact.

*Mr. C. A. Marsh:* To me there seems to be two things requiring immediate decision; one is *how* and the other is *where* shall we start. As has been said, our Harbor Commission has gone into the matter well and deeply, and has made certain recommendations. So the thing now before us is to get started! Schemes and air castles are beautiful and delightful, but they lead to nothing unless we have a starting place and a foundation upon which to start. There are three possible schemes by which the work may be done: By the city, by a private company or by the Sanitary District. These three plans are before us for discussion and enlightenment, and I am sure our time cannot be better spent than in looking into them.

*Mr. Ford:* In regard to the cost of lighterage service, I will say that it will be taken care of by one of the carriers. If it is through business, it will be taken care of by the lake line or the rail line with which it connects. In solving this question of a harbor, the fact should be taken into account that the large carriers of 550 to 625 feet in length and 50 to 60 feet wide, that carry from 10,000 to 13,000 net tons in bulk, have no reason at present to come to Chicago, because they are built for a special purpose, which is to run between an ore dock and South Chicago, the steel works at Gary, and Indiana Harbor. They do not carry package freight, and when they take coal at all it is because they are unable to get ore and they take coal to a modern dock. Sheboygan is the most modern port on this lake. The boats that will come to Chicago will be somewhere from 3,500 to 9,000 tons.

*Mr. Charles W. Naylor, M. W. S. E.:* I wish to introduce something from the standpoint of a dweller on the south side. I can assure Mr. Mershon that there will never be an estuary where a bridge will have to be placed over it.

*Mr. Mershon:* The proposition is to have subways, not bridges.

*Mr. Ford:* I would like to ask Mr. Mershon if a cut anywhere between Sixteenth street to Thirty-ninth street would not meet the same opposition as did the Sanitary District channel on the North Shore. That was opposed most strenuously until it was agreed that no boats would be allowed to pass through it, because they smoked and whistled.

*Mr. Mershon:* But this is only about six blocks long; a very short piece.

*Mr. L. E. Cooley, M. W. S. E.:* I presume that this subject matter will not be disposed of at this meeting, and that we shall have the problem before us for some little time to come. I am on record upon this matter. I appeared before the Harbor Commission and discussed the subject matter one afternoon, and also wrote a paper on it that was published in the Record-Herald a couple of years ago, and to my mind the situation has not

changed greatly since I wrote "The Lakes to the Gulf Waterway" in 1891, at which time I discussed at great length the whole harbor subject of Chicago and its future. What I then predicted has come to pass, that we would uproot the commerce we then enjoyed at Chicago, but that we could not transplant it.

It has always appeared to me that there were two factors in this problem. First and foremost is the sanitation of the city. Of course necessary sanitary measures must be carried out in the vicinity of where people live and can not be located at some remote or distant point. The same thing is true of commerce. Commerce is an incident to population. People will gather in cities for the purpose of transacting business and changing commodities through industries to other commodities, but primarily all means of commerce and all occupations of the city are incidental to the transaction of commerce, which is the business of a city. Therefore, facilities for commerce must also come where people live, must be provided so as to be most convenient for them. There is also a special factor in this question; that is, the waterway to the Gulf. That will also, in my judgment, follow facilities, and the provisions it is necessary to make in this city for its sanitation will provide for its harbor and for its commerce. If we had involved only the matter of commerce by lake and its relation to rail commerce, all the discussion which I have listened to I think would be germane, but in view of this other factor, which I believe will prove to be the greatest factor in the problem, we must of necessity produce a great channel to Lake Michigan. Not two channels, but one channel, because one channel is a ship canal; two or more channels are ditches. When that great channel is produced, in my judgment the harbor becomes a mere incident to it, and it serves all three purposes—not only of a ship canal but of a harbor—for a harbor, as well as for sanitation, and in the best possible relation to the population of this city. When we have solved the sanitary question properly and sufficiently, and have produced what is necessary in connection with the waterway from the Gulf to Lake Michigan, the harbor problem itself becomes comparatively cheap, to my mind—much less expensive than any of the solutions that I have seen proposed. We are not quite up to the question yet. It is fruitful, however, to get all angles into view. I think we will be up to it in the course of about twelve months more.

I have indulged my dreams, as many of you are now doing, in regard to the future of Chicago, but I began a generation ago and so have had the benefit of having some of the dreams come true, and I expect more of them will be made good. My dream in this connection is something like this: That we are to produce a great waterway to the Gulf, fed eventually by all the surplus waters of the great lakes, and that this channel is to extend behind us down through the State of Illinois, and along

that channel is to be located substantially the manufacturing industries of the United States between the City of Chicago and the City of St. Louis, and it will be a continuous harbor and an industrial region all the way. It will occur to you from a sanitary standpoint that the only rational and cheap way to take care of all the sewage products which an enormous population will produce, is for it to locate along this channel. That is a vastly better proposition from an economical standpoint than to go on to develop Chicago, if it were to continue to develop indefinitely in a thin line along the lake shore, which will give us new problems to be solved at infinite cost in the future.

When I was Chief Engineer (the first Chief Engineer) of the Sanitary District in 1891, I had as a consulting engineer the distinguished Chief Engineer of the United States Army, General John Newton, of Hell Gate fame, and in discussing this matter I called his attention to the Sanitary District law, the condition upon which the State of Illinois had entered into that legislation; that it was the basis of a waterway as well as of sanitation and meant the future harbor of Chicago. The matter was discussed at length and the conclusion which the distinguished gentleman arrived at was this: "Mr. Cooley, you will never carry it out. There are too many things to think of at once."

*Mr. Bernard J. Mullancy, Secretary to Mayor Busse* (by letter): The adjournment of the General Assembly without action of any kind touching the Chicago Harbor opens the door for calm and business-like consideration of harbor improvement and development in the concrete. By all means let us have such consideration, unmixed with politics, fad promotion, hobby-riding, or selfish personal scheming.

During recent weeks, when the so-called Ton bill, conferring harbor and dock building powers on the Sanitary District, was pending at Springfield, we were regaled through the newspapers and otherwise with much hectic discussion of harbor questions. Certain persons and interests of widely different affiliations seemed to be agitated to the verge of apoplexy. Yet with all of the uproar, we (the lay public) heard least from those quarters whence the most accurate and most intelligent discussion should have come, namely, engineers who have had harbor experience; vessel men who know the Chicago Harbor and its needs as the average householder knows his back yard; and the commercial and shipping interests which must use whatever additional improvements and facilities are added to the Chicago Harbor.

Questions similar to those raised by the Ton bill will be raised again. One of the best ways of getting ready to meet them is to take stock of what we have and then study, in the concrete and in detail, what we think we need, lest we start spending our money before we are sure of getting value for it.

On January 10, 1910, the Chicago Record-Herald printed an April, 1910

editorial giving a masterly array of reasons for calling the Lakes to the Gulf Deep Waterway project "a fake in all its parts." On January 23, 1910, the Chicago Tribune said: "It is the fate of the Illinois deep waterway to have reached a state of academic discussion at about the time when it was expected that steam shovels and drills would be at work on the water course."

Is there not some resemblance—at least an analogy—between the deep waterway and the Chicago harbor situation? Is there anybody in Chicago whose conclusions are entitled to unquestioned acceptance; is there anybody in Illinois or in the United States who is prepared to say *now* exactly how, where, and to what end we should commence immediately to spend millions of dollars of public money on harbor development and public dock building?

Shipping, like any other form of commerce, follows the line of least resistance. A harbor, no matter how commodious, will not attract shipping unless the harbor be so situated as to serve a commercially economic purpose. Given the harbor and the shipping that would naturally seek accommodation therein, the dock equipment needed to serve that shipping will come. But to talk of embarking upon an ambitious scheme of dock building, as contemplated by the Ton bill, constructing not only docks but the warehousing and railway and mechanical equipment that goes with them, the first step in harbor development looks like putting the cart before the horse. A harbor without railroad connections is worthless; coal docks cannot serve grain boats; lumber, flour, or package freight cannot be handled at the same wharves with iron ore.

It would seem to be the simplest business prudence to refrain from starting ambitious construction of docks, wharves, warehouses, railway terminals, etc., at public expense until several important factors in harbor development shall have been more fully worked out and expressed in the exact terms of arithmetic. Some of these questions are: The bridge question; the question of co-ordinating local harbor plans with federal government plans (Uncle Sam helps little places like Waukegan and Sheboygan when he gets a chance and will help Chicago, although Chicago has virtually spurned his aid in the past); how wide and how straight the Chicago River can be profitably made, considering the value of the property along its banks that must be condemned; how far outer harbor development should be permitted to vitiate the Burnham plan for the lake front; what kind or kinds of shipping are to be served by the Chicago harbor improvement; how contemplated schemes impinge upon the rights of private interests which are notoriously tenacious of even the color of merchantable rights.

Natural commercial causes, quite as much as harbor conditions, have all but eliminated lumber and ore traffic from the

Chicago River. Some coal will continue to come in, and grain to go out, by the river because it must, in spite of bridge and other obstructions. The movement of this traffic ought to be facilitated as much as may be, but it is yet to be shown whether any plan of harbor improvement contemplating municipally owned docks, wharves, warehouses, railway terminals, etc., would materially increase this trade. How much shipping, then, if we except package freight and passenger traffic, remains to be conserved and encouraged by elaborate dock and warehouse building and general harbor improvement? And to accommodate this shipping, is revolutionary legislation and enormous expense necessary? The necessity has not been shown.

Some slight broadening of the city's powers to control or regulate concerns doing business on the river and along contiguous waters may be advisable. But what more is needed? Chicago has always had ample power to police the harbor, establish dock lines and wharfage rights, prevent river and harbor obstruction, and so on. It has slept on its rights, and by so doing has lost much advantage that it might have had from co-operation with the national government. This neglect has lost us some, if not much, shipping business that might otherwise have been retained. These losses cannot now be repaired by legislating in a different direction.

Captain D. Sullivan, general manager of the Great Lakes and St. Lawrence Transportation Company, one of the best informed practical vessel men in Chicago, says: "The Chicago River is being constantly improved and, with the removal of the center pier bridges as contemplated and their being replaced by bascule bridges, we will, when that work is completed, have the finest river for commercial purposes on the Great Lakes, with more dock frontage and better facilities than any other lake port. The greatest trouble Chicago has, in my opinion, is her knockers who work overtime at their profession."

Without opening up the whole subject of public ownership, one may venture the timid suggestion that no acute demand has arisen for legislation authorizing a headlong plunge into the "construction, ownership and operation of docks, wharves, warehouses, elevators, railroad terminals and all necessary appurtenances," at great expense to the people. The lake cities which, we are told, have taken away the shipping rightfully belonging to Chicago, have had no advantage over Chicago which could have been, or can yet be, offset by public ownership of docks, wharves, and all the rest of it. Those cities have simply co-operated with the national river and harbor improvement service—have given that service a chance to help them—in keeping their harbors unobstructed. Private enterprise has done the rest—supplied the docks and other harbor facilities, as it always will. Nowhere in America has it been demonstrated that public

ownership can do better work than private ownership. The largest and probably the best ore docks in the world are at Allouez Bay near Superior, Wis.; the best equipped coal dock on the lakes is at little Sheboygan, Wis. Public ownership legislation was not necessary to bring either of these harbor facilities into existence.

A moment ago I said "revolutionary legislation." That meant the so-called Ton bill at Springfield—a bill that was not only revolutionary but revolutionary backward.

The trend of public thought and expression in this community for years, beginning with abolition of the town governments, has been toward consolidation and co-ordination of governmental powers; toward reduction, instead of multiplication, of taxing bodies. On that, public opinion has been practically unanimous. The Ton bill went the other way, toward extension and perpetuation of the powers of a governmental agency which was created for doing a specific piece of work. That work is still far from finished. Why not let the Sanitary District Board do what it was raised up to do, and let its completed work be judged, before clothing it with absolutely new, and unnecessary, functions?

To say that the Sanitary District would be, financially and otherwise, better able than the city to handle dock building and harbor improvement is the merest subterfuge. The Sanitary District is already bonded, we are told, up to within \$4,000,000 or less, of its limit. And the Calumet channel, which is to cost more than twice \$4,000,000, has not yet been dug.

But suppose the conditions were exactly the reverse, what then? During the last regular session of the General Assembly, there was objection to giving the city means of issuing more bonds because it would raise taxes. That objection became so potent that the legislature made a law prohibiting bond issues by cities without submitting all proposed bond issues to direct vote of the people. The law does not apply to the Sanitary District. After giving the Sanitary District dock building powers, is it intended to let it pile up a bonded debt on the people of Chicago (the people of Chicago pay practically all of the money that goes to the Sanitary District) without the people having a word to say about it?

There is a law question, too, that must be faced in the Supreme Court if legislation like the Ton bill ever passes, to wit: Does transfer of the city's harbor jurisdiction, in part, to the Sanitary District, the bonded debt of which covers practically the same property as the bonded debt of Chicago, amount to an evasion of the constitutional inhibition against any municipality going in debt beyond five per cent of its assessed valuation? This question has not been squarely before the Supreme Court. It was raised in the case of *Wilson vs. Board of Trustees* (133 Ill.

433), but was thrust aside as not properly belonging in that case. The court said: "It will be quite time enough to meet that question when it shall arise."

An advocate of the Ton bill (a member of the Sanitary District Board, I believe) has been quoted as saying that the Sanitary District Board is "closer to the people" than the city government is, and, therefore, is more to be trusted to carry on harbor development in strict accord with the people's will. Let us see.

The term of Sanitary District trustees is now six years. Three of the board's nine members are elected every two years, at the regular fall general election, when nominations and election results are almost certainly confined within strict party lines. As candidates, they go before the people as a small fraction of a big "blanket" ballot that carries the candidates for state and county offices, for Congress and for the State Legislature. Their importance is always overshadowed by that of the candidates for big county and state offices and, every four years, the candidates for governor of Illinois and president of the United States. Fancy the Sanitary District Board and its line of policy or action "close to the people" under those circumstances!

On the other hand, one-half of the members of the City Council are elected every year. As candidates they go before the people at a spring election, when issues are entirely municipal and when non-partisan voting is at the maximum.

Let us look at the "close to the people" suggestion from another angle. The Sanitary District election of November, 1905, was held under circumstances that brought candidates and issues closer than ordinarily to the people. Yet the total vote cast within the city for all candidates for president of the Sanitary District was only 180,952. At the city election in the following April, with none but aldermanic candidates running, the total vote was 264,483. Not much room for difference of opinion there as to which government, Sanitary District or city, is closer to the people.

The Sanitary District's history hardly guarantees consistent development of a logical policy. It is not forgotten that the district entered a few years ago upon river deepening and widening, as a means of getting the requisite legal flow through the river without creating a dangerous current. That policy was abandoned before the work was finished. At least one bridge that the present board agreed to build has not been built.

It may be argued that the Sanitary District Board enjoys a large degree of public confidence and therefore should be entrusted with large powers. Who can guarantee that the next board will enjoy or deserve public confidence? Who knows anything about the way the board does business or about the tangible results of its expenditures? It will be time enough to

heed the argument of confidence in the board when the board really gets close to the people.

Again, why not think a little more closely—and clearly—on this harbor question, lest it reach “the stage of academic discussion,” only after the money is spent? It would seem that the need of immense docks, to be paid for by the people and to be owned and operated by a local government board, is not excruciatingly acute. There is less acute need for spending a lot of money on public ownership of docks, warehouses, etc., along the drainage canal. And if that “fake in all its parts,” as the *Record-Herald* calls it, the Lakes-to-the-Gulf Deep Waterway, 26 feet through the valley, ever becomes a reality, we won’t need such harbor facilities. The big boats will steam past us and go on to St. Louis, New Orleans, Panama, and the Orient, leaving us with nothing to satisfy our yearnings for maritime greatness except a lot of unused docks, ornamented with handsome bronze plates, to tell posterity who were the Sanitary District trustees and the engineers that built them.

*Mr. A. Bement* (closure for the committee): Colonel Townsend has presented most valuable discussion. His statements regarding the advantages and possibilities of lighterage service are most useful as affecting the situation at Chicago. The extensive lighterage service at New York illustrates what may be accomplished in the way of satisfactory and economical freight transfer, not only between railways and shipping, but between various parts of that city and those of New Jersey. He also calls attention to the nuisance and damage that would occur should it be necessary for a large traffic to pass through the center of the city on its way to and from a deep waterway channel.

Mr. Mabbs has suggested a scheme of large proportions. It is interesting as illustrating the magnitude of the problem as it presents itself to those who have given the matter limited analysis. Plans for development should be based rather on the actual necessities of the situation.

In reference to the construction of the proposed breakwater, using the broken stone now on the banks of the Drainage Canal, it should be said that the quantity available is very small compared with what would be required in such a large work. The stone is also of a very small size, and for this reason it could be used only as a core for an embankment, which would have to be covered with very much larger material to prevent washing away.

It is probable that the presence of such a breakwater just inside the waterworks cribs would result in an accumulation on its lake side, reducing the depth of water at the cribs from such cause. In fact it may be that a bar is now forming along this line.

Mr. Mershon does not favor docks on the lake front. It is, however, not necessary to rely upon the almost unanimous opinion of engineers that lake front dockage is desirable, because answer to the proposition may be had in the development at Gary and Indiana Harbor. The reason for selecting these locations was because they were on the lake front, making it unnecessary for ships to traverse a long and narrow river channel obstructed with bridges. This is the best and most definite answer that can be offered to arguments for inland harbor facilities.

In reference to the suggestion for a channel between the lake and the river, between Twelfth and Twenty-fifth streets, assuming that it would be desirable, it would meet so much opposition from interests which would be injured, that damages together with its cost would make its execution impracticable. This proposition, however, has been discussed in detail elsewhere.\*

There should be no feeling that there is competition between the Chicago River and the Calumet locality, because this territory is all Chicago, and it is desirable that development in the southern part of the city be encouraged.

Mr. Hooker asks, concerning details for beginning work, how the railways and shipping are to be brought together. It is almost unanimously agreed by those who have given the whole harbor problem attention that the best, or, to be more exact, the first locality at which lake front docks should be established, is at the mouth of the river. It is true that there is but limited railway connection to this point. It would be impossible, however, to select a location reached by all of the railway lines. The lake front, in the vicinity of Sixteenth street, is nearer to a large number of railways than any other point. These lines, however, could not reach these docks without an expenditure of a very large sum of money for the development of elaborate terminals, and then only a portion of the railway lines would have direct access to the docks. This would not be a convenient location for a lighterage service, because lighters would have a long route in the lake and exposure to more or less rough water, or else would require the protection of a breakwater all the way between the docks and river. Thus, as it is difficult to bring railway tracks to docks, the easiest scheme is to transport loose freight and loaded railway cars from the rails to the docks and from the docks to the rails. This is not only the least expensive means of making connection between docks and rails, requiring only a minimum investment, but it can be soonest established. The matter of convenience, as far as the lighterage service is concerned, is a factor of importance, and for this reason the location

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\*Journal W. S. E., Vol. XIV. P. 781.

of docks at the mouth of the river is of advantage. Thus, the two immediate requirements in this connection are the establishment of the docks at the mouth of the river and the building and putting into commission of the lighters.

Mr. Cooley's argument is for a ship canal through Chicago to connect with a proposed deep waterway to the Gulf of Mexico, and it appears to be his opinion that when deep water transportation is established over this route, the Chicago harbor problem will automatically settle itself.

According to this, improvement of Chicago harbor conditions would be a long way off. It is evident that he does not favor the use of the proposed Sag Valley sanitary canal as an entrance to a proposed deep waterway. It must necessarily follow, therefore, that he would have all shipping pass through Chicago on the way to and from this proposed waterway, which, if successful as a highway for commerce, would bring about a condition in the Chicago River which has been described by Colonel Townsend, and instead of arriving at a time when we could have fixed bridges over the Chicago River, it would probably be necessary to remove bridges entirely on the main river and south branch.

His argument is also for the utilization of the Drainage Canal and the continuation of the proposed deep waterway as a location for docks, rather than the lake front. He calls attention to the fact that sanitation for a large community could be better handled along the Drainage Canal and in the Desplaines Valley than anywhere else, and for this reason the growth of population along the waterway is desirable, in preference to its being adjacent to the lake shore. From the simple standpoint of sanitation, he is, of course, correct. Sanitation, however, is something which comes about after people are located. Their place of habitation is necessarily governed by business and commerce. For some years prior to the time the industries in the vicinity of Gary and Indiana Harbor were established, the sanitary canal afforded deep water navigation. Notwithstanding this, we are confronted by the fact that these large industries were located on the lake, regardless of the advantages for sanitation along the canal. As Mr. Cooley has stated elsewhere, it is observed that "the Almighty has located all the waterways alongside of the big towns." This explains why Gary and Indiana Harbor and the lake are together instead of these towns and the Drainage Canal.

It would be of general service and assistance in understanding the economic possibilities of a Lakes-to-the-Gulf Deep Waterway, if Mr. Cooley would at some time present an analysis and review of the traffic available for such proposed deep waterway.

The harbor matter appears to be very largely a terminal problem, when viewed from the standpoint of interchange of freight between business establishments, docks, railway freight

houses, and transport of goods by wagon. At present, terminal facilities are inadequate, expensive, and inconvenient. Thus, one of the most important factors involved is this terminal situation. Ships cannot deliver goods at mercantile establishments, and the loading and discharge of freight at railway docks is difficult and expensive, because it requires that a steamer spend a long time on the river, moving from place to place, experiencing delay at bridges and in loss of time. The movement of merchandise to and from docks necessitates a large amount of expensive transport by wagon often from long distance. There is also a large amount of merchandise which is transported to and from various points in the city by wagon, much of which could be moved at much less expense by means of a regularly established system of lighterage on the rivers. Thus, lighterage would become a convenient and low priced system of local transportation with various stations at which freight could be gathered, to be distributed to steamer and railway docks and mercantile establishments, now being handled by wagon at high cost. For illustration, a manufacturer located in the northern part of the city may wish to use the Santa Fe railroad for shipment of goods. This involves an entire day's journey of a team to go and return, as the nearest freight house of this railroad is located a long distance to the south. With a lighterage service, the team would go to the nearest freight receiving station, from which the goods would be taken by the next lighter and be delivered to the Santa Fe dock at comparatively small expense.

It is altogether probable that the great economic possibilities of an adequate lighterage service is not realized, nor is it generally known that there are a large number of industries and mercantile establishments that are looking forward hopefully to the establishment of such service.

In recent years a number of mercantile industries have selected locations on the river and have erected large buildings thereon. No doubt many people consider the erection of these buildings as an evidence that the usefulness of the river is disappearing and that such locations have been selected because of the low price of such real estate, brought about by the discontinuance of the use of the property for dock purposes, and that there is no necessity for the development of harbor facilities if docks are to disappear in this manner. This is, however, a wrong view. Real estate people are authority for the statement that dock property brings a higher price than other land just back from the river, and that the locations for these mercantile buildings were selected on the river with the expectation and hope that freight may be economically handled by water. It necessarily follows that, as mercantile establishments increase, freight transportation business will grow and develop in proportion, and that if it is not handled by water it must be done in some other manner. Under these conditions, it is not convenient or economical for a steamer bringing a miscellaneous cargo of mer-

chandise to peddle it out at various locations along the branches of the river, and it is desirable that there be an accessible dock at which to discharge the entire cargo, which may be distributed by lighters, tubes of the Illinois Tunnel Company, or by wagon as best suits the case.

As illustrating the unsatisfactory condition of terminal facilities, it is reported that sugar is now received at Milwaukee by water, brought to Chicago by rail, and distributed by the Pugh Terminal Company, because facilities for discharging cargo are enough more favorable at Milwaukee than Chicago to compensate for the additional rail charge from that port to this city.

The committee feel that the more important constructive features of the harbor problem may be summarized in the following seven items:

(1) That the best location for the establishment of new docks is on the lake front at the mouth of the Chicago River.

(2) That the easiest, least expensive and, at the present time, most feasible connection between rails and docks in an outer harbor may be established by means of lighters transporting either railway cars or loose freight.

(3) That a lighterage service between different points on the river would afford a new and valuable system of transport for handling goods in competition with teams, which would result in economy as well as relief from congestion in the city streets.

(4) That while it is desirable to keep as much large shipping out of the Chicago River as possible, so that the interruption to traffic crossing bridges may be reduced to a minimum, hardship should not be imposed on shipping which finds it necessary to discharge and take cargo at docks located on the branches of the river, and to accommodate such business old bridges should be replaced by new and the rivers otherwise improved.

(5) That if an entrance to a deep waterway, through the Desplaines Valley to the Mississippi River, becomes necessary, such entrance should be in the Calumet District, by way of the Sag Valley.

(6) That the development of the Calumet River be carried out, with a view to making it an inland harbor, rather than the Chicago River.

(7) That such improvement as may be made in harbor facilities should be upon a plan which will impose the lowest possible tax on shipping.

What may be termed the legislative situation is at the present time the most significant and important feature of the harbor problem. The discussion from Mr. Ewen and Mr. Mullaney shows this very clearly. The city is not in a position to do anything, and the Sanitary District has been suggested as being able to take over harbor matters and develop, for Chicago, har-

bor facilities in the same manner that it created a sanitary system. To this scheme there is considerable opposition. If harbor improvement is to be made by the people at large, instead of by a private company, it is, of course, by all means desirable that it be done by the city government. The situation, however, is in a manner equivalent to that which existed when the Sanitary District was organized. Chicago at that time demanded protection for the city's water supply; this required the canal and other works which have now been constructed. Chicago was in no position to raise the necessary funds, or to assume jurisdiction over territory outside of its corporate limits, and the situation was got around by organizing a separate municipality with taxing power to do for the city what it was unable to do for itself. Thus, we are confronted with a situation as follows: The city itself is powerless. The Sanitary District is considered by many to be in a position to undertake the work; yet there is a strong feeling in the community that the activities of the Sanitary District have already become too numerous; in addition to sanitation it has gone into the electric business, and now it is proposed that it add harbor business, which is a very large proposition.

The Committee of the City Council on Harbors, Wharves and Bridges has prepared a tentative ordinance for the Pugh Terminal Company (the only bidder), which would bind it to such performance as to make it possible for it to successfully build and operate docks and a lighterage system. The City Council is confronted with a difficult problem in dealing with a matter of this character, because a precedent for short-term franchises for public utility grants and a share in profits has been established, which, in the case of harbor facilities, if followed, will place a tax on shipping that will result in diverting business to other ports. Thus, the situation resolves itself into two possibilities: One, that the city and the Pugh interests come to an agreement; the other, that the city and the Sanitary District trustees jointly work out some scheme. It appears, however, that before such scheme can become effective, favorable legislative actions by the General Assembly must be secured. Of two measures before the recent session of the Legislature—one to give authority to the city to construct and operate harbor facilities, the other to empower the Sanitary District to take over the harbor—both failed to pass.

A conference between the Sanitary District trustees and the city authorities is planned for the near future, but at this date, March 18th, the governmental aspect, to which Mr. Ewen makes reference, is quite acute. In the meantime the city of Milwaukee is planning to spend a large amount of money in the establishment of convenient docks and other harbor facilities, not for the purpose of realizing direct revenue as a tax on shipping, but to develop the resources and business of that city.

# THE PANAMA RAILROAD AND ITS RELATION TO THE PANAMA CANAL.

RALPH BUDD, M.W.S.E.

*Presented February 2, 1910.*

At intervals since the discovery of the Pacific Ocean by Balboa in 1513, the improvement of transportation facilities across the Isthmus of Panama has attracted the attention of various nations and capitalists.

The first move was the opening of a trail about the middle of the sixteenth century by Spain. It ran from Porto Bello, an old fort about fifteen miles down the coast from Colon, to the old City of Panama. A little later this route was improved upon by using the Chagres River from its mouth at Fort Lorenzo, about ten miles up the coast from Colon, to Cruces, and from Cruces to Panama City by trail.

This latter route continued popular until the completion of the Panama Railroad in 1855, and was used by the gold seekers en route to California in the early 50's.

The completion of the Panama Canal remains to afford unobstructed trans-Isthmian traffic facilities.

The Panama Railroad Company was organized in 1850. Construction work began the same year and the road was completed and put in operation in 1855. The difficulties overcome by the early engineer parties were almost insurmountable; in addition to the inevitable difficulties incident to the unhealthy tropical climate and the dense jungles, every possible obstacle was placed in their way by the owners of the pack-trains and the fleets of canoes who had, with the rush of the gold seekers to California, built up a very lucrative business. The fact that the line as built lies directly on the route, and in many places within the prism of the Panama Canal, as located after the completion of exhaustive surveys and the preparation of complete contour maps, speaks for the character of the original railroad location work. The railroad as first built had a very narrow road-bed both in embankment and excavation. It was originally built with softwood ties from southern United States. The torrential rains soon necessitated the improvement of the road-bed by widening cuts and fills and by ballasting, and the short life of ordinary timber led to the use of lignum vitæ ties. The road was built 5 ft. gage and has always been so maintained, all of the tracks on the Isthmus, both Panama Railroad and Isthmian Canal Commission, now being of this gage.

During French Canal times—1881 to 1904—the Panama Railroad was controlled by the French Canal Company, but the road has been practically always managed by Americans. It has always been prosperous and always well enough maintained to safely and expeditiously handle its business.

The whole organization of the Panama Railroad Company is subsidiary to the Isthmian Canal Commission, and its chief business is in facilitating canal construction. The Chairman and Chief

engineer of the Isthmian Canal Commission, is also President of the Railroad Company, while the Commissioners are members of the Railroad Company's Board of Directors. The General Manager of the Railroad, who has charge of operation and construction work, also has the title of Assistant to the President and reports directly to him.

#### REBUILDING THE OLD RAILROAD.

The road is 47.7 miles long. On the advent of the Isthmian Canal Commission in 1904, it was handling a freight traffic of 17,000,000 ton miles annually. It was early decided to use the Railroad to haul away the excavated material from the Culebra Cut, as ample space was found on low ground along the Railroad where dumps could be developed quickly and cheaply without the necessity of building separate tracks to reach them. This use of the Railroad, and the shipments of all the material and supplies incident to work on the Canal, increased the tonnage in the years 1906-7 to 42,000,000 ton miles; during 1907-8 to 150,000,000, and in 1908-9 to 280,000,000, probably the maximum, as the Culebra Cut proper is being shortened by completion of the Canal near its ends, and the development of large new dumping ground along the re-located line of the Railroad will tend to decrease the tonnage hauled over the present operated line.

To prepare for the great increase in traffic, the Railroad has been almost entirely rebuilt, and 37 miles of it was double tracked. The work of rebuilding and double tracking was practically completed at the end of the fiscal year 1907. The portion double tracked is mostly built on embankment, so that the grading for double track was an unusually simple and economical proposition: namely, that of unloading dirt trains from the Culebra Cut along the main line and widening the fills thus built sufficiently to carry another track. There were a few cuts, the larger of which had to be taken out with steam shovels. In order to avoid delay to the shovel and interruption to traffic that could not be eliminated from steam shovel work, small pan cars (old French Decauville cars) of about  $1\frac{1}{3}$  cu. yd. capacity were used in all cases where the material could be disposed of within reasonable distance. Some of the smaller cuts were taken out by hand-work with wheelbarrows. For the most part, however, the work of double tracking consisted of widening the original embankments sufficiently to support a new track, then moving the new tracks over to 13 ft. centers by unloading filling from it and keeping it thrown over to the edge of the bank. The equipment used consisted of Western dump cars and flat cars unloaded by side plow Lidgerwood unloader. Both McCann and Jordan spreaders were used for leveling the fills. In locating the second track it was shifted from one side to the other of the old main line at many places to better the alignment, to save cutting, or to improve the vision for safety of operation. In some places great improvements could be made by surprisingly small effort. An instance of this is between Juan Grande and Gorgona, (Fig. 1) where 731 ft. of distance,  $104^{\circ} 34'$  of curva-

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ture and four ft. of rise and fall were eliminated by building 3,300 ft. of line across a valley which was filled by dumping excavated material from the canal. There were practically no sidetracks on the old line prior to the Isthmian Canal Commission days, few being needed. A timetable as of June, 1904, shows ten house tracks, five of which were spurs, and four passing tracks, the total length of house and passing tracks being a little less than 10,000 ft. Sixteen house and commissary tracks have been built, having a total length of 17,100 ft., and eight passing sidings having a total length of 12,300 ft. In addition, 64,500 ft. of yard tracks were built at Cristobal and La Boca (now called Balboa). The old depots were of shed type 16 ft. wide and 80 to 100 ft. long; one end being enclosed for agent's and operators office, and the other for freight; the middle portion served



FIG. 2. CULEBRA DEPOT—TYPE USED ON THE OLD LINE OF THE PANAMA R. R.

as a shelter for passengers. These depots were altogether inadequate for the requirements. Twelve new passenger and freight depots were built at the most important places and five were remodeled.

The Culebra depot is shown in Fig. 2, and is typical of those which were newly built. These are frame buildings with corrugated iron roofs, and are 30 by 126 ft., the passenger, office, and freight sections being 30, 20, and 76 ft. respectively. The passenger room is not enclosed, as will be noticed in the view. Five-room living quarters are provided in the second story for the agent.

During 1906-7 all tracks were laid with 70 lb. Bessemer steel rails, which replaced the 56 and 60 lb. rails in use on the old road. On the eleven-mile section from Las Cascadas to Tabernilla, where the traffic is most dense, the 70 lb. rail was replaced with 90 lb. Bessemer steel rail in January, 1908. On all of the curves in this section the



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90 lb. Bessemer rail has been replaced with 90 lb. Open Hearth steel rail of carbon content 0.70% to 0.80%, and phosphorus 0.03% to 0.05%. This rail is giving much better service than the Bessemer, but it has been in the track only since April 25, 1909, so full comparisons cannot as yet be made.

Data in reference to rail wear on an 11 degree curve is given in Fig 3. Manganese steel frogs are used in turnouts leading to and from the Canal where traffic is most dense. They have proven very satisfactory and indicate a life of five or six years where Bessemer steel, spring rail frogs had to be changed every four months. One regrettable thing in preparing the Panama Railroad for handling the Canal Commission traffic and maintaining it under this traffic was the necessity of replacing the *lignum vitæ* ties in the old track with cypress ties. These old ties had been in the track from ten to thirty years, and many of them were as sound when removed as when first

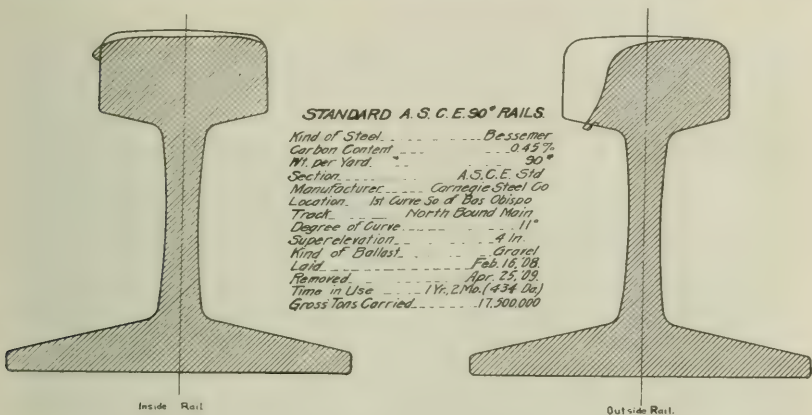


FIG. 3. WEAR OF RAILS.

laid, but they were all pole ties having a face of from 6½ to 7 inches, and were from 7 ft. to 7 ft. 9 in. long. They presented such small bearing surface that it was impossible to maintain the track under the traffic that was imposed. Use has been made of them in house tracks and yard tracks, and as fence posts; of late they are also being used by the Isthmian Canal Commission in making steam shovel jack blocks.

The maximum train load on the Isthmus consists of two 120-ton locomotives followed by a trainload of 4,400 lb. per lineal foot. All bridges on second main track were built for "Cooper's E-50" loading, and all of the bridges on the old track were strengthened accordingly. Pile bridges were used on the second track throughout. In order to avoid interruptions to traffic a pile driver was spurred on the widened embankment. Where the bridges were very short, however, the piles were driven from the machine standing on the old line. There are 65

bridges in all; from 12 to 150 ft. in length. Practically all were too light to carry the new cars and locomotives. Most of them were iron or steel spans, ranging from 50 ft. down, and were easily and cheaply strengthened by driving pile bents under them to shorten the span. A notable exception was the bridge across the Chagres River at San Pablo, known as the Barbacoas bridge. This consisted of six wrought iron through plate girder spans from 101 to 109 ft. long. Instead of double tracking this bridge, a gauntlet track was laid across it, using No. 12 frogs. The north three spans of this bridge are over the river channel, and it was therefore impracticable to put supports under the middle of these spans on account of the drift-wood during the rainy season. Three new spans were therefore put in place of those, and a new floor system put in the three old spans, which were then supported by steel bents placed under the middle of each of them. The new girders were put in at the beginning



FIG. 4. REPLACING 109 FT. GIRDER SPAN BARBACOAS, WITH STEAM WRECKERS.

of the rainy season, when falsework could not be held in the channel except immediately on the down-stream end of the piers, and built as extensions to them. The new spans were therefore installed in the following manner: A span complete, including the deck, was loaded on flat cars and set immediately over the place where it was to be installed. The new span was then blocked up on the old girders and the flat cars taken away. A 75 ton steam wrecking car was brought up against each end of the new span, and the span lifted bodily and held suspended in the air, while the entire old span was

pulled down stream onto the falsework. This was accomplished by two Lidgerwood unloaders, which stood on the track at the end of the bridge, and each of which handled one end of the old span. After the old span was removed, the new one was lowered into place by the wreckers. The entire operation consumed about four hours for each span placed. The work was done on three consecutive Sundays.

In Fig. 4 is shown the second span being placed. The total weight of the span, complete, when handled by the wreckers, was 115 tons. Fig. 5 shows a plan and section of the old wrought iron girders. These girders were installed about 1870; the exact date is not known.

The majority of the loaded dirt cars handled over the Panama Railroad tracks are what are called "Lidgerwood Flats." They are flat cars with a 3 ft. sideboard on one side, and with a 12 in. extension of the car floor on the other. When heavily loaded, as they usually are, the center of gravity is about 15 in. from the center of the track, and about two-thirds of the weight is on one side of the car. This creates a very peculiar condition for track maintenance. In order to avoid derailment of these loaded cars it is necessary to adopt  $3\frac{1}{2}$  in. as the maximum super-elevation for the outer rail on curves, regardless of the degree of curvature. With this super-elevation very few derailments occur, but with all other track conditions practically perfect and 6 in. super-elevation on an 11 degree curve, five derailments have taken place at the same spot in one day. This unusual number was due to the fact that, early in the day, a loaded train with the heavy side of the car over the low rail, was flagged on the curve, and in slowing down became derailed, due to the decrease of centrifugal force, which would have prevented derailment at the higher speed. While no damage was done to the track by this train, the train crew reported the derailment and a slow order was placed, with the result that within the next few hours and before the cause of the trouble was discovered, four cars in other trains, especially badly loaded, were derailed in a similar manner. Reduction in super-elevation from 6 to  $3\frac{1}{2}$  in. prevented further trouble, although all trains run slow during the next twenty-four hours while damaged ties were being replaced.

#### THE RELOCATED LINE.

In general, the Panama Railroad was built from Colon to Gatun, a distance of seven miles across a salt marsh. Here it reached the Chagres River and followed the Chagres Valley, keeping more or less closely to the river for a distance of twenty-four miles to a point near Bas Obispo, where the Chagres makes a decided turn to run parallel with the continental divide, while the Railroad keeps its general direction following the Camacho River up very nearly to the summit at Culebra, and then, after crossing the divide, it descends the Pacific Slope in the Rio Grande valley. The Atlantic Slope from Colon to Bas Obispo is quite flat, the elevation reached at the latter point being 85 ft. above the sea. Since the water in Gatun Lake will be normally at that elevation, it is apparent that all of the present



line between Gatun and Bas Obispo will be submerged when the lake is formed. Similarly the lake will submerge the section of track from Miraflores to Paraiso on the Pacific side. Moreover, the Railroad now crosses the Canal in two places—once at San Pablo, and again at Paraiso. The section from Colon to San Pablo—23 miles long—lies on the east side of the Canal; the middle section—San Pablo to Paraiso, 17 miles long—lies on the west side, and the southerly section from Paraiso to Panama—7 miles—is again on the east side.

These conditions necessitate the construction of a new Railroad to take the place of the old one from Gatun to Miraflores. The minimum elevation of sub-grade for this new Railroad through Gatun Lake (Gatun to Pedro Miguel) has been fixed at 92 ft. above sea level, except at points opposite Gatun and Pedro Miguel, where the sub-grade is 95 ft. As the present line between Colon and Gatun, and also between Panama and Pedro Miguel lies only a few feet above sea level, it is necessary to begin the relocation at sufficient distance north of Gatun and south of Pedro Miguel to attain an elevation of 95 ft. on reaching these points. On the north end the new line joins the old at Mindi—2½ miles north from Gatun—and on the south end the junction is at Corozal—4 miles south of Pedro Miguel—a greater distance being used on the Pacific end because there are two sets of Locks—one at Pedro Miguel and one at Miraflores—making an intermediate lake at an elevation of 55 ft. just south of Pedro Miguel. The entire length of the relocated line from Mindi to Corozal is 40 miles.

Location parties were put into the field in September, 1906, under the direction of the Assistant Chief Engineer of the Isthmian Canal Commission. The location was completed in March, 1907, and the right-of-way was practically all cleared by the end of April.

From Mindi to Gatun the line lies along a chain of hills, which affords support to gain the necessary elevation at Gatun. From Gatun to Bas Obispo the line was located along the east side of Gatun Lake. From Bas Obispo to Pedro Miguel it will occupy a 40 ft. berme left in the east slope of the Canal at an elevation of 95 ft. above sea level. From Pedro Miguel to Corozal it crosses two deep valleys and passes through the Miraflores ridge in a tunnel; the fills across these two valleys were made of waste material from Culebra Cut.

On May 23, 1907, the construction of the relocated line was turned over to the Panama Railroad under the direction of the General Manager. During the fiscal year of 1907-8 work was confined to three districts where the construction of the new line would materially aid the Canal Commission plans. These three districts were as follows:

First, Work in the vicinity of Gatun in order to abandon the old railroad tracks which occupy a portion of the site of Gatun dam.

Second, Construction of Gamboa bridge and three miles of track to open up dumping grounds.

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Third, Construction of two large culverts near Miraflores to admit of enlargement of dumps, and the construction of Miraflores tunnel.

The work in the first mentioned section consisted of building the new line from Mindi to Gatun and building a temporary track from Gatun to join the old line at Tiger Hill two miles south of Gatun. The temporary line crossed the Gatun River and its wide, low valley, and was so located that the permanent embankment, when built, would include the temporary fill within its prism.

Gamboa bridge carries the relocated line across the Chagres River. It is located at the north end of Culebra Cut near Bas Obispo, where the Chagres River enters Gatun Lake. In the three miles north from Gamboa the relocated line crosses several streams having large valleys which afford dumping space for about 10,000,000 cu. yds. of material. Gamboa bridge made this dumping ground accessible from Culebra Cut. The bridge is 1,325 ft. long and consists of fourteen 80 ft. through plate girder spans and one 200 ft. through truss of the Warren type, all resting on reinforced concrete piers and abutments. The bridge is built for "Cooper's E-50" loading and under the 1906 specifications of the *American Railway Engineering and Maintenance of Way Association*. The top of rail elevation is 99 ft. and the lowest member of the bridge is 93½ ft., that is 8½ ft. above the level of Gatun Lake. The French Canal Company had built a bridge at this place, of which two truss spans, respectively 100 and 200 ft. long, were still standing. Although too light for heavy traffic, they were valuable for construction work. A temporary trestle was built from the north end of this old bridge, 18 ft. centers, from the new bridge to a point beyond the north abutment. The south end of the old bridge was connected by tracks with the tracks in Bas Obispo cut; over this track and bridge, all material for construction of the piers was handled, and the trestle served in place of falsework for the girder spans. All erection was done by the Railroad Company's forces. The truss span was erected with a locomotive crane on falsework. The girders were shipped to the Isthmus in three sections each, and were set up and riveted in the Gorgona shops of the Isthmian Canal Commission. They were shipped to the bridge site standing upright on flat cars and were erected by two locomotive cranes, one of which stood on the temporary trestle which was connected up with the old French bridge, and one on the last completed span of the new bridge.

In Fig. 6 is shown the new bridge nearly completed, and the old French bridge and trestle which was connected up and used for falsework, while Fig. 7. shows the two locomotive cranes placing a girder.

The two 20 ft. by 24 ft. reinforced concrete arch culverts were built between Pedro Miguel and Miraflores to carry the Pedro Miguel and Caimetillo rivers respectively. The construction of these culverts allowed the development of dump grounds in the river valleys, and gave access to the north end of Miraflores tunnel, work on which was also carried forward during the fiscal year 1907-8.



FIG 6. GENERAL VIEW OF GAMBOA BRIDGE LOOKING SOUTH INTO CULEBRA CUT.

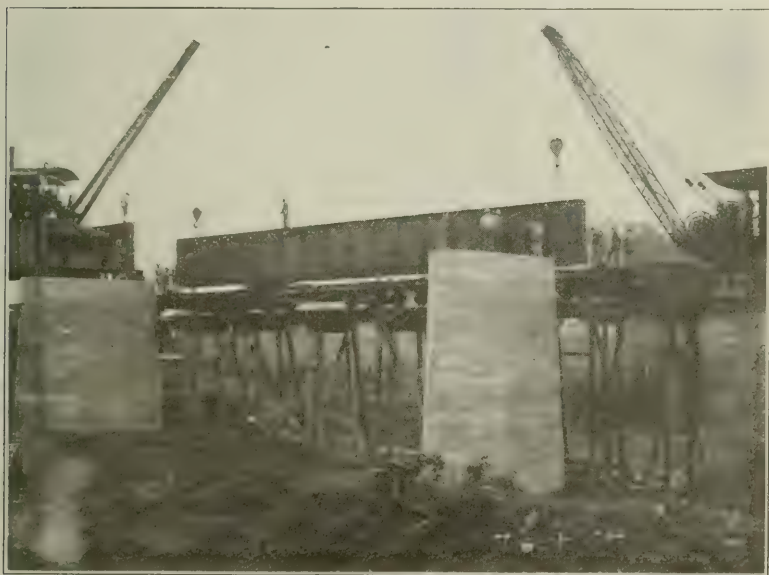


FIG. 7. PLACING A GIRDER BRIDGE WITH LOCOMOTIVE CRANES.

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During the fiscal year of 1908-9 construction work was carried on over the entire line, and continuation of the progress now being made will see the track connected up throughout by April 1, 1910, except that portion which lies in Culebra Cut proper.

While building a temporary line around Gatun dam, investigations were made to determine the character of the underlying strata in the Gatun River valley, across which it was necessary to build the temporary line. It was found that there was an upper layer of 25 ft. of clay and sand over irregular alternating layers of very soft clay, sand and silt, while rock was 200 ft. below the surface of the ground. Experience in building a short fill across a small valley near the main Gatun valley demonstrated that embankments could not be built across these Gatun bottoms at any ordinary slopes, and that the side slopes would necessarily be as flat as 5 or 6 to 1, instead of 2 to 1 as originally contemplated and as used elsewhere on the line. The valley in question is 6,500 ft. long, and the surface of the ground is 8 ft. above sea level. To build an embankment with subgrade at 92 ft. above the sea, with a top width of 40 ft. and side slopes 2 to 1, as originally contemplated, would have required 4,200,000 cu. yds. of material. To build this embankment at the same height and of the same top width, but with side-slopes 5 to 1, would a little more than double the embankment quantities, requiring practically 9,000,000 cu. yd. of fill. Investigations were begun, looking to the abandonment of this enormous embankment. The construction of a steel viaduct was considered, but the idea was abandoned on account of the expense of maintaining it, as 76 feet of the towers would have been submerged by Gatun Lake.

In February, 1908, parties were put into the field to seek a new location further up the Gatun valley. No construction work had at this time been started between Gatun and San Pablo. The original location made in this section by the Isthmian Canal Commission engineers, had skirted along the eastern border of Gatun Lake, following around the west end of several ridges that are in general direction perpendicular to the line. A better crossing was found about four miles up stream, but to go so far up stream to cross the valley and then to come back again to join the original location around the west ends of these ridges, made the line very long and crooked. It was proposed to build the line from Mount Hope (1½ miles from Colon) to this upper crossing, and to operate a spur line from Mount Hope to Gatun (5½ miles), but this was abandoned because it was desired to have Gatun and its permanent activities on the main line. The desirable thing to do, then, since it was necessary to go so far eastward to improve the bottom, was to keep the line back from the east border of Gatun Lake and to cross the ridges instead of passing around to the west of them, and then to join the original location at a point about two miles south of Bohio, where the border of the lake and the original location turn back eastward on account of the topography of the country. This



FIG. 8. GENERAL MAP OF PANAMA R. R.

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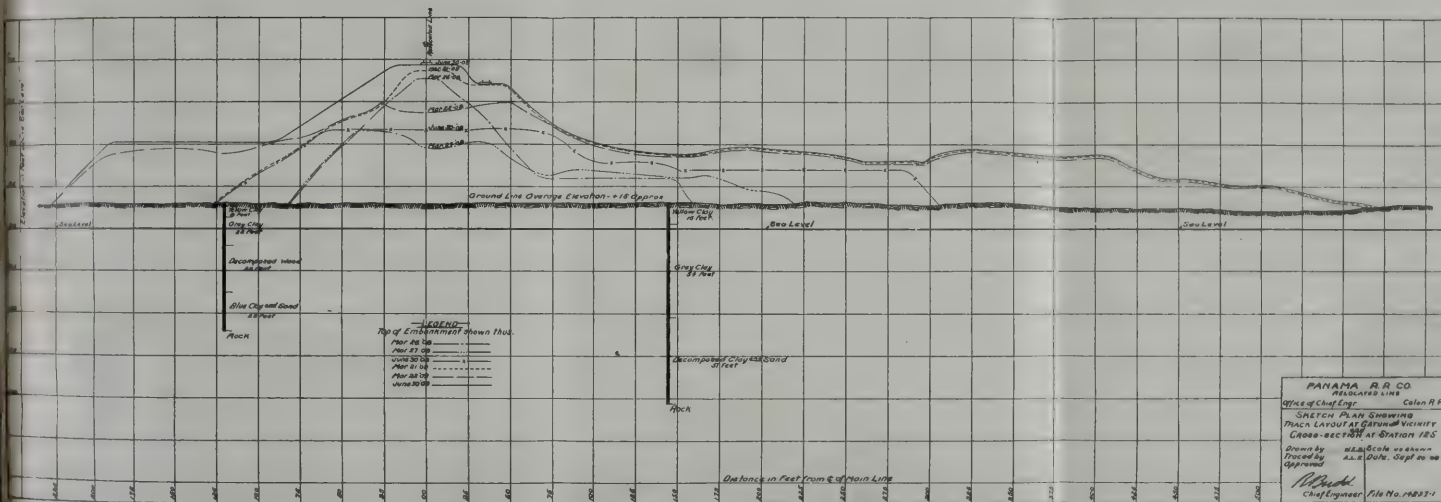


FIG. 9. EMBANKMENT, SOUTH OF GATUN—ON SOFT GROUND.

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would not introduce any considerable distance, since it would place the line on the north and east sides of a quadrilateral, along the west and south sides of which the original location was made.

The ordinary reconnaissance in this country is practically impossible, but contour maps, showing 10 ft. contours below elevation 90, completed about this time by the Isthmian Canal Commission, indi-

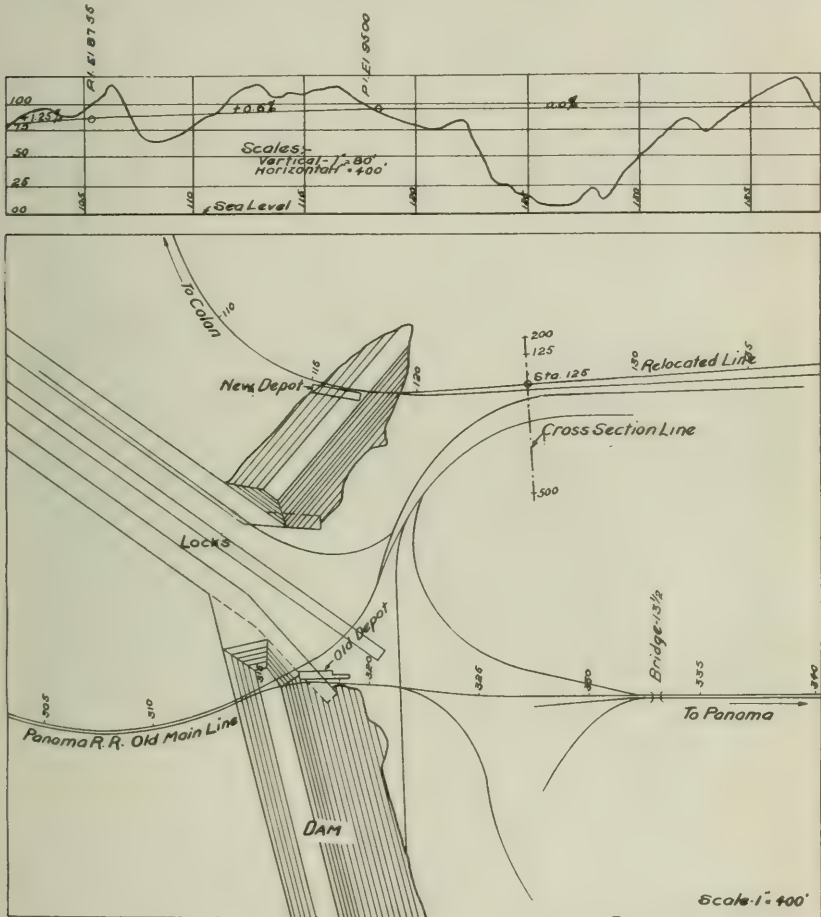


FIG. 9A.

cated the possibility of such a change, and showed that the ridges were narrow in places. Surveys were made along the Bohio, Agua Salud, and Baldo Espino ridges, seeking low saddles where the contour maps indicated, through which a location could be made. Such saddles were found and the line relocated accordingly. A further change was made between Frioles and San Pablo along the same April, 1910

lines; that is, moving the line back from the edge of the lake into the hills. The map of the Canal Zone, Fig. 8, shows these changes. In addition to greatly reducing the amount and degree of curvature, these changes in location also give a line which can be shortened five miles by building a four-mile freight cut-off from Mount Hope to join the line again just north of Gatun River crossing, as is also shown in Fig. 8. This is the line on which it was proposed to build and operate a spur track from Mount Hope to Gatun.

#### SOME UNUSUAL FEATURES IN CONSTRUCTION.

At a point 800 ft. south of the Gatun Station a high embankment carries the relocated line across a valley 1,600 ft. wide, which joins the main Gatun valley at this point. Seven hundred feet of this embankment is from 80 to 85 ft. high, as shown on the map and profile attached, Fig. 9. The permanent relocated line occupies the center of this embankment, and along the west side is the temporary connection track, known as the  $1\frac{1}{4}$  per cent line, which leads from the relocated line at Gatun Station (elevation 95 ft. above sea level) to the old line at Tiger Hill (elevation 22 ft.). The valley which this embankment crosses will eventually be an arm of Gatun Lake. It was originally planned to build this fill in three decks and to use the excavated material from Gatun Locks. This material being entirely rock, side slopes of  $1\frac{1}{2}$  to 1 and top width of 30 ft. were planned. The base of the fill up to elevation 30 above sea level, containing 80,000 cubic yards, was placed as contemplated during the months of September, October, November, and December, 1907. In the months of November and December, 1907, a connection track 2,000 ft. long was built from the Gatun Lock side in order to place filling from the second deck, a trestle 30 ft. high being driven across the embankment at an elevation of 60 ft. above sea level. This trestle was filled during January and February, 1908, without serious difficulty, the only occurrence being a slide where the embankment crossed the old creek bed and involving movement of about 5,000 cu. yds. of material. This was not considered unusual, as it is a condition commonly met in such work. During the night of March 26th, after completion of the third deck trestle, which was driven at the elevation of the  $1\frac{1}{4}$  per cent Gatun-Tiger Hill line, and after about 100 ft. of this trestle had been filled from the north end (elevation 90 ft. above sea level at this point), a very large slide occurred, carrying the tracks on the first and second decks several feet out of line and lifting the ground at the base of the embankment 10 to 12 ft. upwards over an area of about 50 ft. by 150 ft. This slide was apparently due to the placing of a large amount of filling against the hillside which rested on an inclined rock surface, causing all the material above the rock to slip. Up to this time, 160,000 cu. yds. of material had been placed in the embankment. Dumping on the center line was now abandoned and the bottom of the embankment was widened by raising the first deck track to elevation 35, and then

throwing it over to the west. This was the condition at the close of the fiscal year June, 1908. The work was continued along these lines until in September, when 50,000 cu. yds. had been deposited as a counter-weight along the west side of the fill. During October, November, December, and January, the fill was brought up to the level of the third deck, a total of 337,000 cu. yds. having been placed up to this time. Throughout this process several bad slides occurred, not through slipping off the steep hillside as at first, but by displacing the clay which overlaid the rock to a depth of 50 to 80 ft. on the east side, and from 100 to 125 ft. on the west. All these slides occurred toward the west. The counterweight had been added to during this period and by the end of January it was very large, mak-



FIG. 10. SLIDE IN GATUN FILL.

ing, together with the bulging up due to slides, a slope of about 6 to 1 on the west side of the embankment. It was now considered safe to raise the embankment to final grade, elevation 95 ft. above sea level. On March 21st, when practically up to grade and when the embankment was considered to be about completed, a slide occurred to the east, or up-hill side, displacing about 50,000 cu. yds. of material, with a vertical settlement of about 30 ft. for a distance of about 300 ft., as shown in accompanying photograph, Fig. 10. In Fig. 11 is shown the same embankment a few days prior to the slide. This was the first movement eastward. The method employed on the west side, that of building a counter-weight, was now resorted to on the east side as well, and after continuing this until June 1st, fill-

April, 1910

ing was resumed on the center line, and by June 15th had reached two feet above final grade, with a top width of 40 ft. and side slopes that will average about 6 to 1 on the west and about 3 to 1 on the east side. The actual amount of material deposited was 528,000 cu. yds. To have built a fill 40 ft. wide on top, with side slopes 2 to 1, would have required 293,000 cu. yds.

Fifteen hundred feet south of the high Gatun fill the line turns sharply to the left and follows along the south side of the ridge, which extends eastward from Gatun Dam and forms the rim of Gatun Lake. The line follows this ridge for about four miles, where it makes another sharp turn, this time to the right, and crosses the



FIG. 11. HIGH EMBANKMENT AT GATUN, JUST PRIOR TO SLIDE.

Quebrada Ancha, Quebrada Baja, and Gatun valleys, which converge into one between here and where the original relocation crossed between Gatun and Tiger Hill. The south slope of this ridge is more or less cut up by gullies, and numerous ridges extend out between these gullies. The method of construction has been to build as much as possible by benching into the side hill and casting over with steam shovels, driving pile trestles across the intervening gullies.

A temporary trestle 250 ft. long and 70 ft. high across one of these gullies is shown in Fig. 12. By this method the track is pushed ahead with the least possible amount of work until the large valleys are reached, when the entire side hill along the ridge can be developed into a borrow pit for obtaining material to make the em-

bankment, at the same time grading a very good roadbed in solid rock excavation, safe from slides, where the completed track will be located.

As the new line lies so far from the present one in the section south of Gatun, it is necessary to build that part of the line between

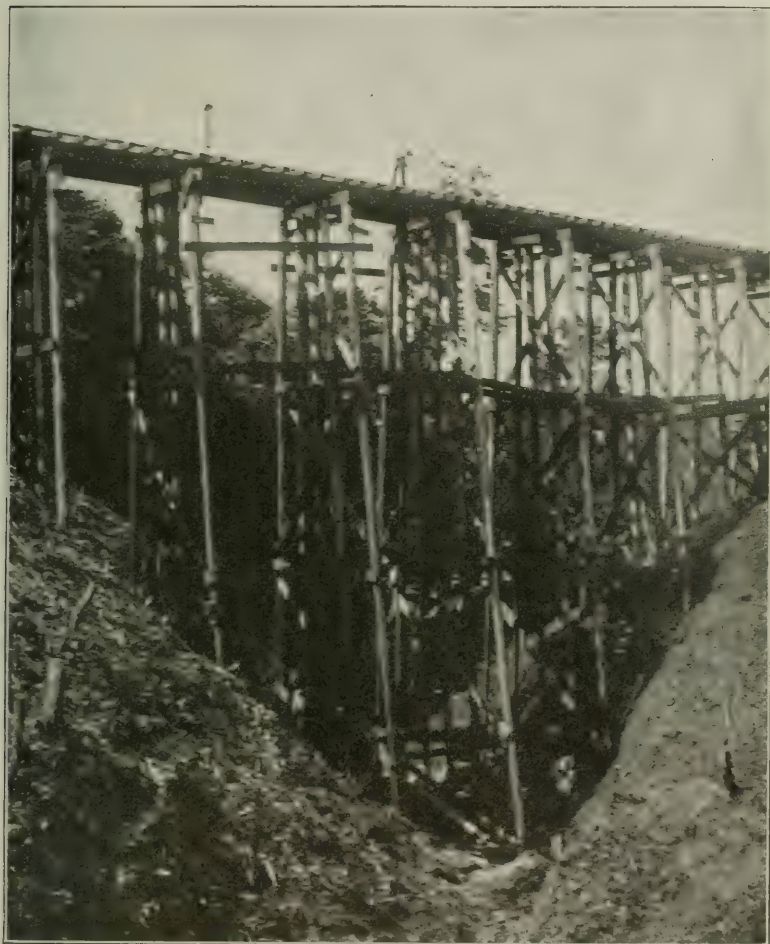


FIG 12. TEMPORARY TRESTLE, ALONG GATUN RIDGE.

Gatun and Frijoles (12 miles) by working south from Gatun and north from Frijoles, no connection tracks being possible from the old line. This kind of construction is most difficult in the tropics, owing to the dense growth of vegetation and the difficulty of getting material and subsistence supplies. The method employed is to estab-

April, 1910

lish camps as far ahead of the tracks as possible, so as to have the cuts excavated in advance of pile driving which is necessary across the numerous wide valleys. Pile driving is hastened where trestles of from  $\frac{1}{4}$  to  $\frac{3}{4}$  of a mile in length are required, by laying a track across the valley and backing a pile driver across on this track, then starting it driving from the far end to meet the driver which starts at the end of the track, the track in the bottom being used meanwhile to supply the materials to the two drivers.

In Fig. 13 is shown two pile drivers about to meet in the middle of a 3,000 ft. trestle and also shows at the left the temporary track. A Lidgerwood unloader is usually employed at the end of the track



FIG. 13. SHOO-FLY LINE USED TO WORK PILE DRIVERS IN LONG TRESTDLE.

in such cases to let down the loaded cars, and to pull up the empties after they have been placed by the smaller engines and unloaded on the lower track.

During the dry months, January to May, 1908, excavation of the Miraflores tunnel bore had been practically completed, and temporary timber lining had been placed throughout almost the entire length.

The north 400 ft. of this tunnel passes through solid rock, and the south slopes of this rock lies at about an angle of  $45^{\circ}$ . The excavation of the south portal of the tunnel so disturbed the equilibrium of the earth which forms the south side of the Miraflores Ridge, which the tunnel pierces, that during the months of July and August

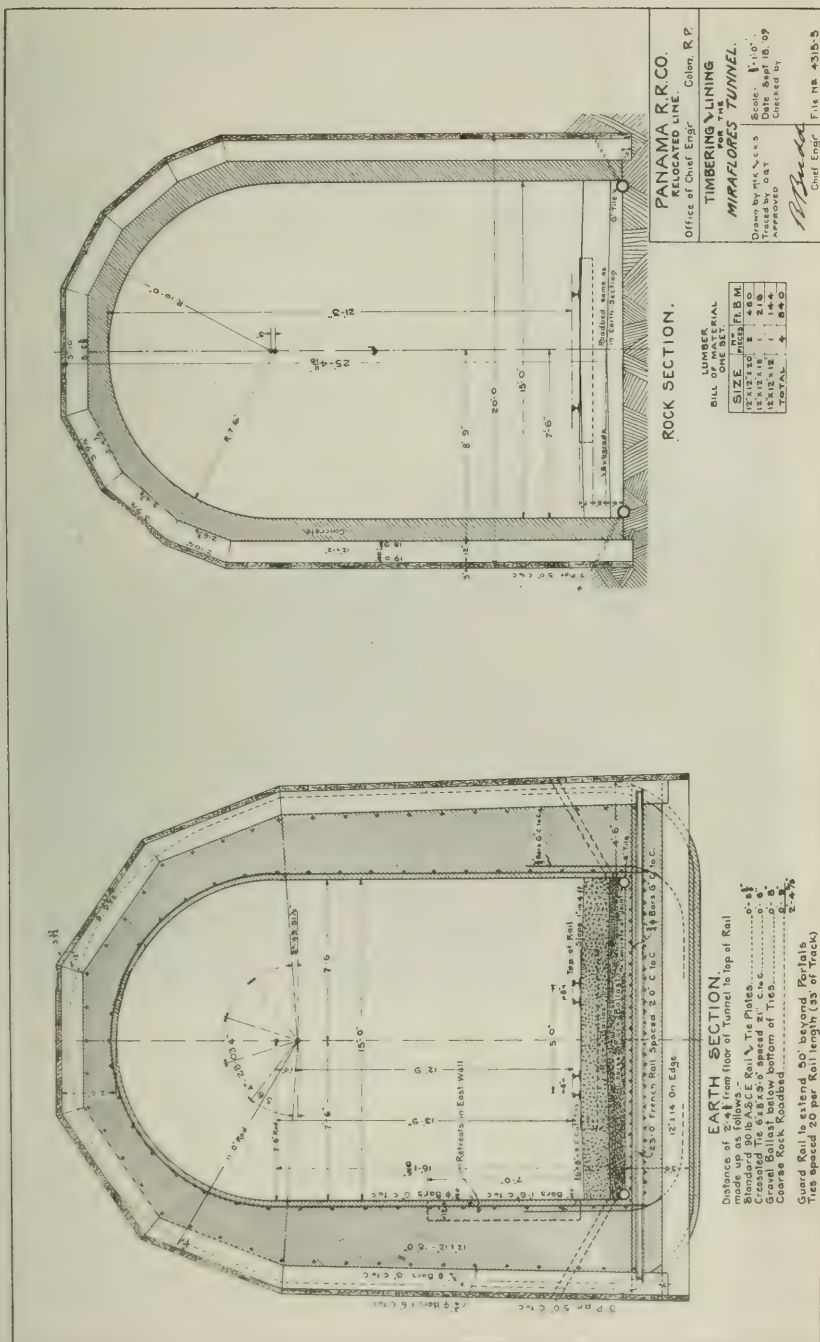


FIG. 14. TUNNEL LINING.

the entire side hill, involving about 200,000 cu. yds. of material, began moving southward along the axis of the tunnel and also slightly eastward, at an angle of about  $20^{\circ}$  from the direction of its axis. This carried the earth section of the tunnel with it and literally twisted the tunnel to pieces. The timbering in the earth section, 200 ft. long, collapsed in September. The rock section, 421 ft. at the north end, was not affected and was lined with concrete during September, October, and November. Work was discontinued in the earth section until the beginning of the dry season, January 1st, when the tunnel was again opened up on the original center line and grade, and was completed in April, 1909.



FIG. 15. SLIDE ON SOUTH SIDE OF MICAPTON RIDGE, SHOWING SOUTH END OF TUNNEL.

The reinforced concrete lining of the earth and the rock sections, also the roadbed as built, is shown in Fig. 14. A track was laid and heavy rock placed to refill the hole in the south side of the hill, caused by the slide. The illustration, Fig. 15, from a photograph, shows this work about completed, and also shows the extent of the slide. The small summit at the right was originally about on the center line. The escarpment on the side of the main hill indicates where the slide broke off. The tunnel was lengthened 50 ft. at the

north end and 91 ft. at the south end, to provide for flatter slopes on the sides of the hill due to slides. Its length on completion was 736 ft. from portal to portal, instead of 595 ft. as originally contemplated.

#### BRIDGES AND CULVERTS.

On the completed line there will be two steel bridges carried on reinforced concrete piers and abutments. One of these, spanning the Chagres River where it enters Gatun Lake at Gamboa, has been described above. The other will be a bascule bridge at the Gatun River. All of the other rivers and streams will be carried through

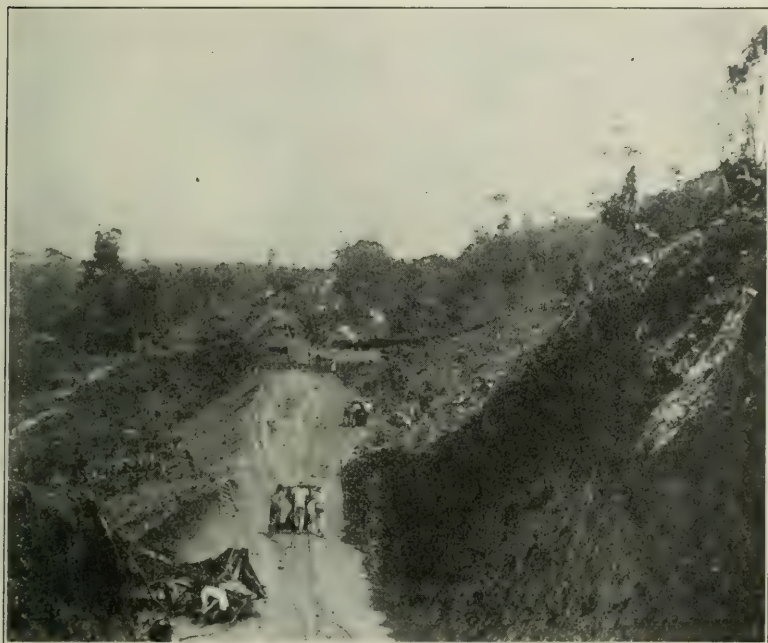


FIG. 16. TYPICAL TASK WORK.

culverts below sub-grade. These culverts are being built from 15 to 20 ft. above the bottom of the stream. The backing up of water is of slight importance for two reasons: *First*, the land is uncultivated and is already owned by the Isthmian Canal Commission, or will have to be purchased before being submerged by Gatun Lake. *Second*, when the lake is formed, all land on both sides of the line below elevation 85 above sea level, will be permanently flooded. By placing the culverts high against a rock side hill, good foundations, without piles, are often obtained, where it would have been necessary to go to great expense had the culverts been located in the

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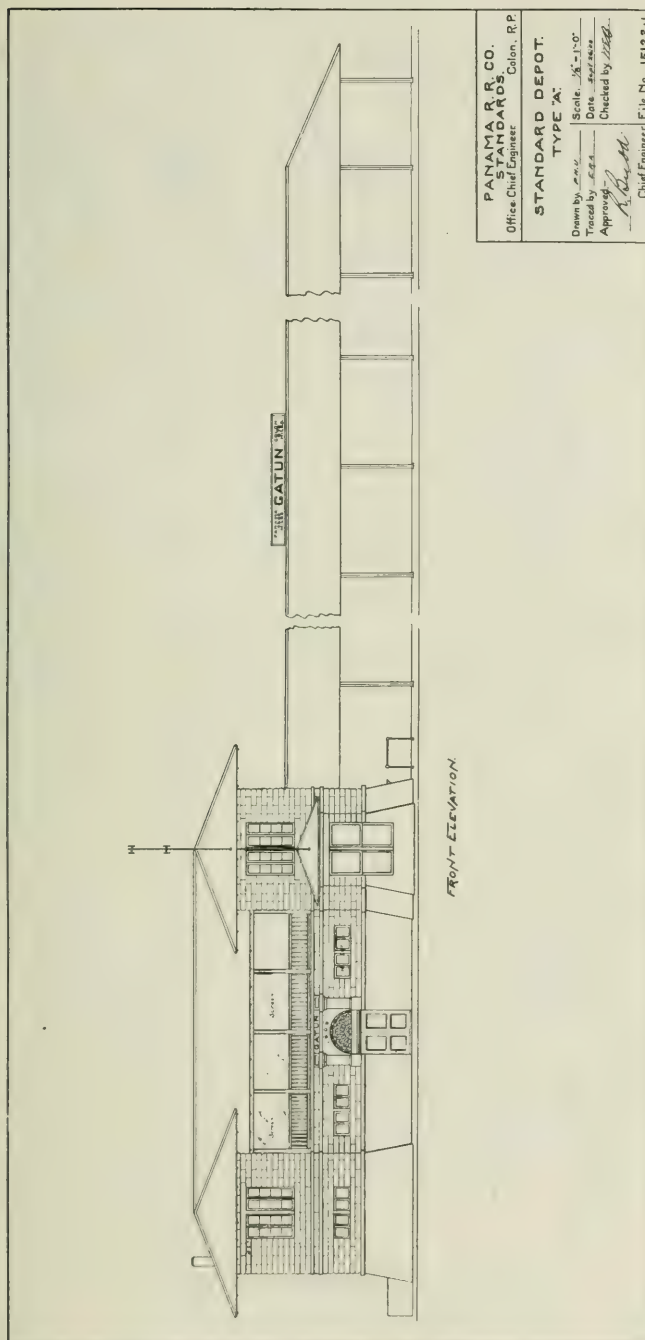


FIG. 18A. STANDARD DEPOT.

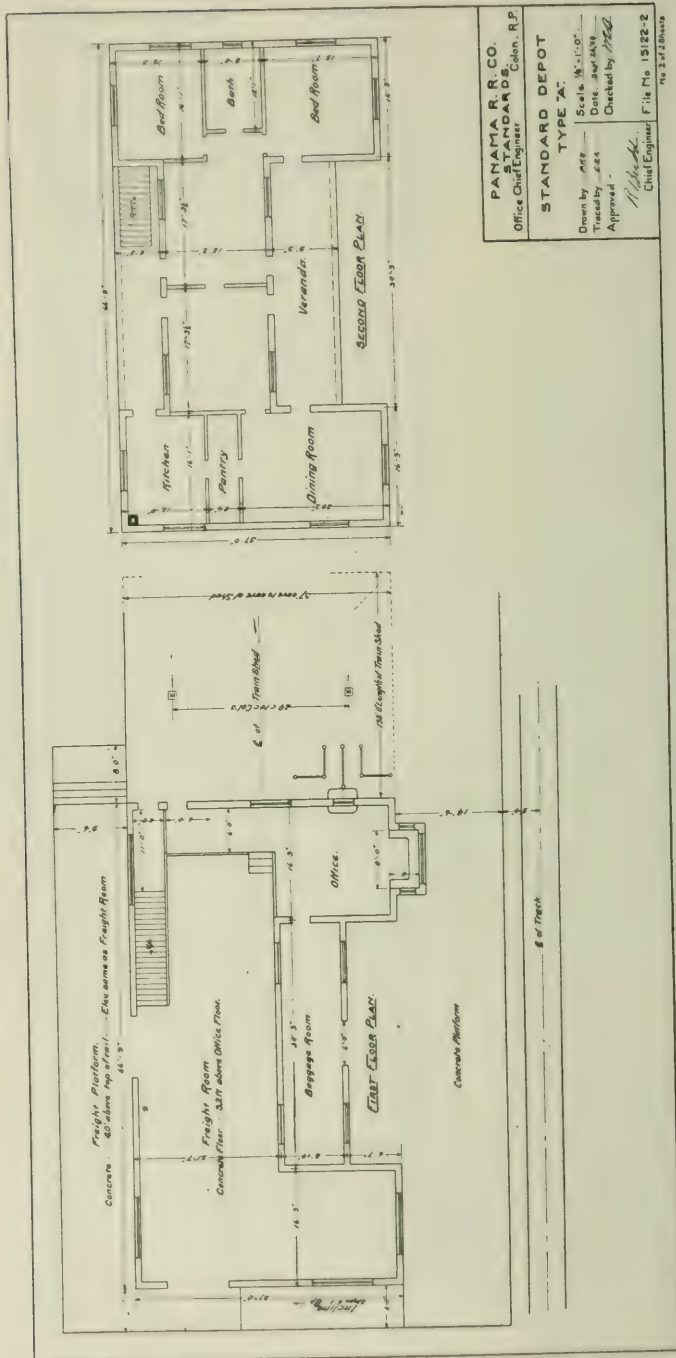


FIG. 18B. PLAN OF GATUN DEPOT.

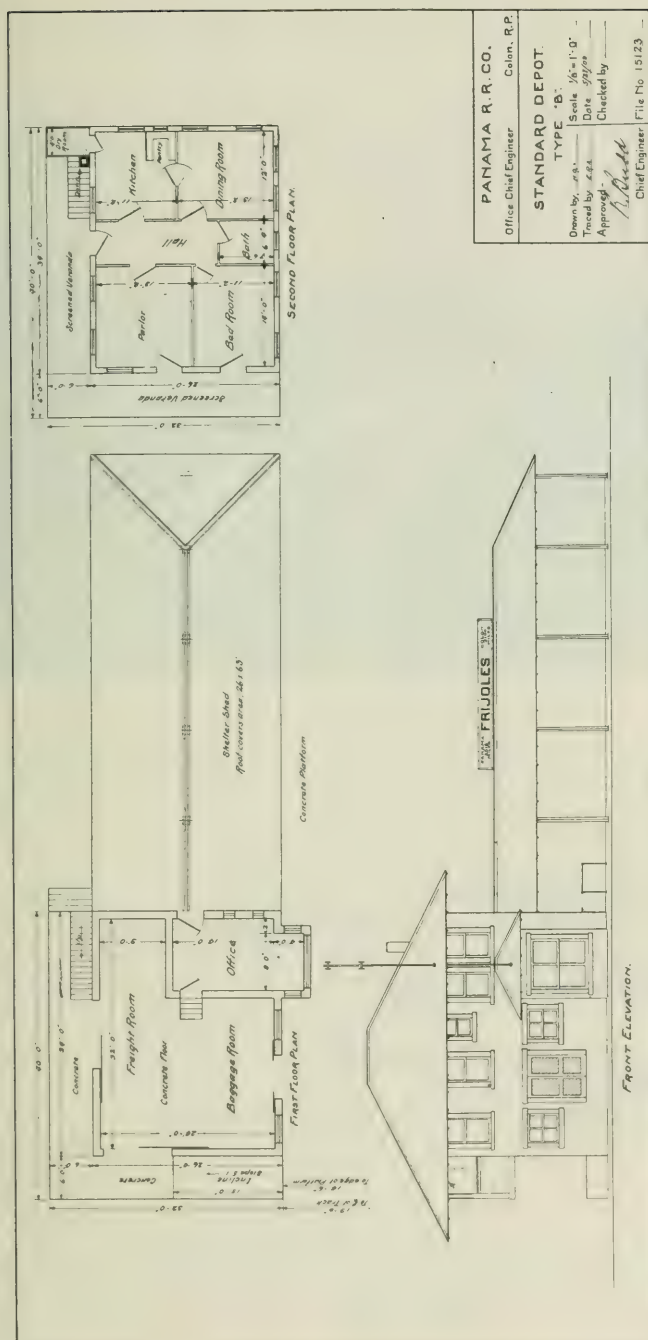


FIG. 19. STANDARD DEPOT PLANS.

bottom of the valley. Furthermore, with embankments having side slopes of 2 to 1, each foot the culvert is raised shortens it by four feet.



FIG. 20. VIEW OF STATION AT GATUN.

Three types of concrete culverts are used: reinforced concrete arches, reinforced boxes, and vitrified pipe culverts. Gravel con-

PANAMA R.R.CO.

DIAGRAMS SHOWING PERCENTAGE OF COMPLETION OF THE RELOCATED LINE.

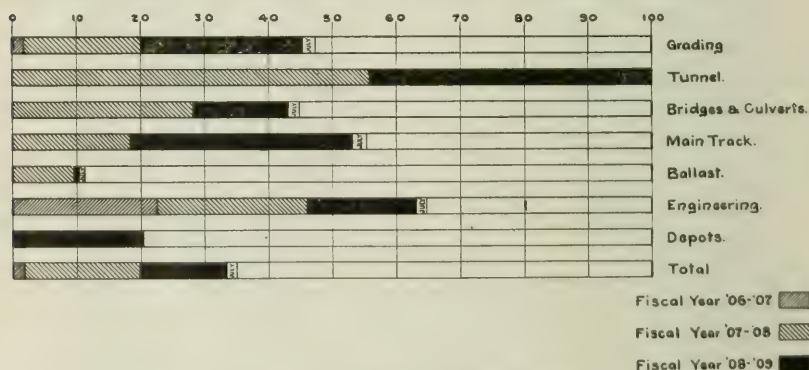


FIG. 21. DIAGRAMS OF WORK DONE.

crete has been used almost exclusively, the gravel being obtained from deposits in the Chagres River.

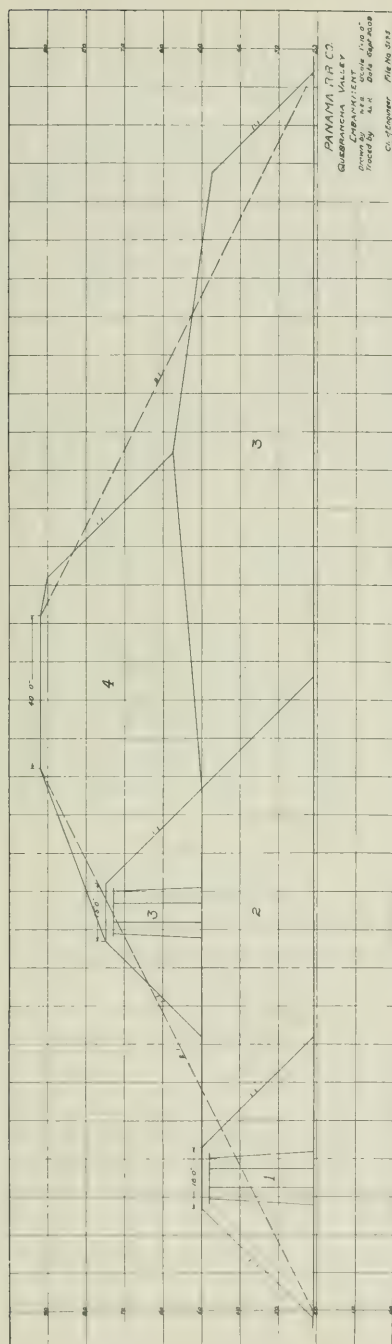


FIG. 22. SHOWS ORDER IN CONSTRUCTION IN HIGH EMBANKMENT.

On all of the smaller cuts, and in many cases to open up for a temporary track to start steam shovels, the so-called "task system" of labor is used. By this method the laborer is paid for carloads of material moved rather than for his time. A price of 8, 9, and 10c for each Decauville car (about  $1\frac{1}{3}$  cu. yd.) was fixed upon, depending on the length of haul and the inaccessibility of the work. No classification of material is made, as the Railroad Company does all blasting necessary to get the rock into pieces small enough to be handled by hand. A West Indian laborer can be employed to especial advantage by this method. A number of negroes co-operate, some doing digging and loading, and some dumping and spreading.

The Company requires that at least fifteen cars be loaded by each

PHYSICAL STATISTICS.		OLD LINE	RELOCATED LINE.
Distance Colon to Panama		47.27 miles	46.18 miles
Number of Tracks		Double Track ~ 32.64 miles Single Track ~ 14.63 miles	Single Track
Gauge of Track		5'-0"	5'-0"
Weight and Section of Rail		19.0 miles Track-90# ASCE Remainder-70# ASCE	70# ASCE
Kind of Ballast		Gravel	Gravel
Total Rise and Fall		427.5 Feet	208.0 Feet
Maximum Gradient-North Bound		1.50% Comp.	0.45% Comp
" " ~ South Bound		1.45% Comp	1.25% Comp
Distribution of Curvature	1°	42° 21'	334° 29'
	2°	264° 42'	419° 57'
	3°	523° 58'	382° 16'
	4°	841° 10'	262° 54'
	5°	587° 49'	101° 00'
	6°	833° 51'	491° 16'
	7°	226° 13'	None
	8°	331° 49'	None
	9°	322° 30'	None
	10°	319° 41'	None
	11°	155° 47'	None
Total		4449° 51'	1991° 52'

FIG. 23. TABLE OF COMPARISON OF OLD AND NEW LINES, FOR ALIGNMENT, GRADES, DISTANCES, ETC.

man for his day's work. Frequently this "task" will be finished in six hours, while on the hourly basis it would hardly be done in nine. A typical "task" gang at work, is shown in Fig. 16.

The section of roadbed used is rather unusual, owing to local conditions. Ample width is required in excavation, owing to the enormous rainfall, and it can be provided without extra expense, as the embankment quantities are so largely in excess. The extra width and flat slopes provided on the embankment are on account of their being submerged, as indicated on the standard roadbed plan, Fig. 17.

Two types of depots are provided, as shown in standard plans,

Figs. 18 and 19. One type "A" depot, has already been built at Gatun, as shown in Fig. 20.

The diagram, Fig. 21, shows the general progress of the work to date. The new Railroad will be practically completed during the present fiscal year, except building the two miles across the Quebrada Ancha, Quebrada Baja, and Gatun river valleys. Track will be carried across these valleys on temporary trestles at a minimum elevation of 50 ft. above sea level, and the embankments will be built by the methods shown on cross section, Fig. 22, the successive operations being numbered from 1 to 4. The total yardage in these embankments will be about 3,500,000 cu. yds. The minimum elevation of the old Railroad in the Gatun Lake region is 20 ft. above sea level. The present line will be used until the water in the Gatun Lake reaches this elevation of 20 ft., when the new line will be put into use between Gatun and Bas Obispo, where a connection will be made by building a trestle across the Canal, as shown in Fig. 8. The old line will then be used from Bas Obispo to Paraiso until the Culebra Cut is completed.

#### DISCUSSION.

*Mr. J. F. Wallace*, M. W. S. E. (by letter): Mr. Budd has presented a very interesting article, one which brings out graphically the difficulties to be encountered in railroad construction in tropical countries. His caption, however, suggests a rather broader treatment of the subject of the relation of the Panama Railroad to the Panama Canal than that contained in his paper, and it might be well to explain somewhat more fully to the members of the society some matters connected with the early history of the Panama Railroad, and later its relationship to the canal project.

It should be remembered that at the time of the construction of the Panama Railroad the Panama route was the principal, and practically the only, line of communication for mails, merchandise and travel between the Atlantic and Pacific coasts of the United States; that there were practically no railway lines west of the Mississippi River and none west of the Missouri, and that it was necessary for the United States Government to have reasonable control over the transit across the Isthmus of Panama in order to protect its mail route and its line of communication between the Atlantic and Pacific coasts—two territories which at that time were separated by some 2000 miles of overland travel by wagon trains and stage coaches, more or less inadequately protected from interference by hostile tribes of Indians west of the Missouri River.

The Panama Railroad Company was chartered under the laws of the state of New York, and its protection was arranged for by a treaty between the United States Government and the Spanish Province of New Granada, which was afterwards

merged into the Colombian Republic and designated the Province of Panama, which latter province, as the result of the revolution of 1903, became an independent republic under the protection and practically the domination of the United States Government.

The original treaty gave the Panama Railroad Company an absolute monopoly of all lines of communication across the Isthmus of Panama, and gave the United States Government the right to control the operation of the railroad and protect it against interference from local and domestic disturbances, or from outside sources of interference. It also provided that the control and operation of the road should be exercised by American citizens. This is the reason why, as mentioned in Mr. Budd's paper, the Panama Railroad has always been managed and operated by Americans.

Later, when De Lesseps applied to the Colombian Government for a franchise to construct the Panama Canal, he was required to accept such franchise subject to the prior rights of the Panama Railroad Company, which, as stated above, enjoyed an absolute monopoly of all methods of transportation across the Isthmus, and the rights of which were broad enough to prevent the construction or operation of a ship canal without its consent.

The problem of obtaining the consent of the Panama Railroad Company was overcome by De Lesseps and the canal company by the purchase outright of practically all the stock of the railroad company, the holdings of the New Panama Canal Company at the time of the transfer of its rights to the United States Government of 1903 being 97% of the entire stock issue.

Later the question of the equity of the private citizens holding the small minority of 3% of the stock raised so many complications that all of this stock was purchased by the United States Government at private sale, so that at the present time the United States owns the entire capital stock of the Panama Railroad Company and connecting steamship line, except single shares nominally in the name of the directors of the Panama Railroad Company, who are mostly members of the Isthmian Canal Commission or other persons in the employ of the United States Government.

It was under the terms of the original treaty between the United States and the Spanish province of New Granada that the United States Government in 1903 claimed the right of intervention, and justified its action in supporting the revolutionary party on the Isthmus, in preventing the United States of Colombia from suppressing that revolution, and in assisting in the formation of the present Republic of Panama.

The fact that the Colombian Government had declined to ratify the treaty which had been for some time under negotiation, April, 1910

tion with the United States for the renewal of the franchise authorizing the construction of the Panama Canal (the rights under which were about to expire), naturally suggested the criticism made on the administration at that time that the revolution and its recognition and support by the United States Government was a necessity, in order to secure the franchise and create a situation that would permit the Panama Canal Company to make a legal transfer of its rights and property to the United States, and enable the latter to proceed with the construction of the canal.

It will therefore be seen that the relation of the Panama Railroad to the Panama Canal has been most important.

At the time of my connection with the Panama Canal (during part of which period I was also Vice-President and General Manager of the Panama Railroad and Steamship Line), the relationship of the railroad to the canal, not only during the construction but after the completion of the canal, was given thorough consideration, and I took a much broader view than merely the use of the Panama Railroad as an accessory to the canal construction.

As the Panama Railroad was an important link in the line of the world's traffic leading through the Isthmian gateway, I held that it should be maintained as such until superseded by the great waterway which we were undertaking to construct; that while the railroad should be used in every possible way for the furtherance of canal construction, its function as a link in international trade should not be overlooked, but should be improved and strengthened and every possible step taken to encourage its use for that purpose, in order that the world's traffic through this gateway might be strengthened and built up, so far as it was possible to do so through the instrumentality of a railroad, with a view of increasing this traffic during canal construction to a point that would enable the time to be shortened during which traffic by this route could be encouraged and developed so as to create a return that would, at least in some measure, justify the enormous expenditure of money required to construct, maintain and operate the Panama Canal.

I considered that the same principle should be adopted in the improvement, maintenance and use of the Panama Railroad in connection with the canal construction as is adopted in the rebuilding or improvement of any trunk line railroad, which is, that all construction work shall be so planned and carried on in connection with the operation of the railroad as to give the minimum interference with the operation of existing lines of transit.

With this end in view I recommended the double tracking and improvement of the Panama Railroad, the provision of wharf and dock facilities, power and equipment, and the employment of every possible means to increase the transporta-

tion facilities across the Isthmus, in order to build up international traffic via this line.

I also recommended the abolition of the existing rates and billing methods, and the substitution therefor of practically a flat rate per ton for the transference of freight across the Isthmus. My recollection is that this recommendation embodied a rate not to exceed \$2.00 per ton, together with the throwing open of this line to the traffic of the world on this basis, and the simplification of the accounts by the collection of this charge on the Isthmus from the steamship lines, thus doing away with division of rates, complicated bookkeeping and creating a situation approximately approaching the conditions and cost of transit per ton which would exist after the completion of the canal, in order that every inducement might be given to the world's commerce to use this route, so that the traffic should be built up and at least partially developed by the time the canal was ready to handle it.

I have always believed, and still believe, that this policy should have been adopted by the United States Government.

It is an axiom and requires no argument to show that the world's traffic will follow the lines of least resistance, and the line of least resistance is cost per ton.

All the traffic which passes through the Isthmus, or ever will pass through it, could be handled by the Panama Railroad, if properly constructed, managed and operated, at a cost of not exceeding \$2.00 per ton, and if, during the first few years of light traffic, this rate (which would give the railroad a revenue of between three and four cents per ton per mile) should show a loss, the loss will certainly be less on the amount of money invested in the railroad and its equipment, plus its maintenance and operating charges, than it would be on the interest on the cost of construction, plus maintenance and operating charges, of the canal.

I do not wish to be misunderstood as advocating the substitution of the railroad for the canal, as I fully realize the importance of ultimately avoiding the breaking of bulk of cargo, as well as the possible benefits of the canal from a naval viewpoint, either in time of peace or war. But the point I am endeavoring to make is that the railroad should have been, and should be used as an instrumentality to encourage commerce to use this gateway and to strengthen and build up traffic pending the completion of the canal, so as to shorten the number of years during which we will be required to operate the canal at a great annual loss.

It must be admitted by all that sufficient traffic to justify the canal construction does not exist today, but must be created, and that a low cost per ton for the transit across the Isthmus, either by railroad or canal, will be an important stimulating factor in creating conditions to cause this traffic to grow,

which must ultimately be brought about by a vast increase in the power to produce traffic by the countries that border on the Pacific Ocean, as well as the subsequent increase in the purchasing power of those countries, and the creation of a demand for the manufactured products of the United States and other countries bordering on the Atlantic Ocean.

Since the first day of operation of the Panama Railroad and Steamship Line, discrimination entered to such a degree in the making of rates that if it existed within the domain of the United States it would have been considered intolerable, and would have been brought to the attention of the Interstate Commerce Commission in short order.

The rates by rail across the Isthmus, or the divisions granted the Panama Railroad in the making of rates in connection with other existing transportation lines, were such that they varied not only in the ordinary classification of products, but also as to their points of origin or destination.

Rates on the west coast were indirectly based on a comparison with the cost of transportation through the Straits of Magellan or around Cape Horn, or as they might be affected by other competition. The proportion of the through rate from San Francisco to New York which accrued to the Panama Railroad for transit across the Isthmus averaged something less than \$2.00 per ton.

This exceedingly low rate, compared with other Panama Railroad rate divisions, was brought about by the competition of transcontinental lines between New York and San Francisco, and developed a most interesting situation, as it demonstrated that the through transcontinental lines practically regulated the rate from New York to San Francisco by way of the Isthmus, instead of the Panama route regulating the transcontinental rates.

When it is considered that the average rate per ton on traffic passing through the Suez Canal is about \$1.50, and that the lowest rate that has ever been suggested for Panama is \$1.00, it can readily be seen what a small margin will exist by this route to affect through transcontinental rates by competition with the railroad carriers, and still more so when the local rates are considered from the interior to the seaboard on either coast, or from the seaboard to point of destination in the interior.

Among the higher rates, if I remember rightly, was that on coffee from Costa Rica, which had to stand a charge of \$6.00 per ton for the 47 miles of railroad transportation across the Isthmus. Other products to and from other countries were in some cases even much higher than this, but they were all exorbitantly high as compared with the revenue which the Panama Railroad derived on through freight between San Francisco and New York, and also exorbitantly high as compared with rates

on traffic of a similar character handled by railroads in the United States.

The situation is peculiarly interesting when we consider that the United States Government attempts to control, through an Interstate Commerce Commission, the traffic on 225,000 miles of railroad in private ownership, and permits this state of affairs to exist on the only railroad under the absolute control and ownership of the government. The only apparent reason for this would seem to be simply lack of proper appreciation of the situation by the authorities at Washington.

It can therefore readily be seen what an impetus would be given to the producing and consuming powers of the countries lying on the Pacific slope if the cost of transit across the Isthmus were lowered to a reasonable amount, as suggested above.

The advantages can also readily be seen which would accrue to the world's traffic by substituting the flat rate on the basis of a transfer charge, and giving all shipping interests the privilege of using this rate as an arbitrary to be added to the regular ocean rates on traffic using this route; as well as the ease and simplicity of its collection and accounting, as against the past and present cumbersome method of complicated classifications and divisions.

In this connection I desire to call attention to the fact that today the Tehuantepec Railroad, across the Isthmus of Tehuantepec, is forming a link in the lines of British traffic from England to the Orient, and that already this line, with 178 miles of railroad over heavy grades connecting the Gulf of Mexico with the Pacific, has succeeded in building up an ever-increasing traffic, which causes apprehension upon the part of the United States Government, as a competitor of not only the existing Panama Railroad, but even of the canal when it is completed.

The continued improvement in equipment and appliances of the Tehuantepec Railroad is creating a traffic route which, in view of the great saving in distance, may prove a strong competitor of the Panama Canal.

*Mr. O. P. Chamberlain, M. W. S. E.:* The officers of the society regret very much that Mr. Slifer was not able to be present this evening. Mr. Slifer, at the time that Mr. Budd was Chief Engineer of the railroad, or during a portion of the time, was General Manager and Assistant to the President of the Panama Railroad. He has recently come to Chicago as General Manager of the Chicago Great Western Railroad. There are some things in connection with this paper which are of interest to all engineers who have been engaged in railroad work. It is evident from this paper, reading, you might say, between the lines, that conditions in Panama for building railroad embankments are such as we find in many places along the eastern coast of this country, and also through some of the low lands

of the West. The difficulty of building fills that will remain in place seems to have been one of the serious things which the railroad management had to contend with. The idea of a railroad embankment with a fill of a slope of six horizontal to one vertical is, to say the least, very unusual in this part of the country.

I was very glad that Mr. Wallace presented his discussion, for it brought out some things which were not touched upon in the paper as presented by Mr. Budd. Mr. Wallace has taken a broad general view of the entire situation, and one of the things worthy of notice in his paper is the fact that while the United States Government, through the Interstate Commerce Commission, is regulating railroad rates in this country, in the operation of its own line it followed the same rule that the railroads formerly followed in the United States, of placing the tariff as high as the traffic will bear. That was to me a very interesting point in his discussion.

Mr. Wallace also brings up the question of the competition of the Tehuantepec Railroad with the Isthmian Canal for the business for which the canal is building. This has been touched upon in the public prints, and no doubt all of you have read that this railroad is operating at the present time with a rapidly increasing business, taking the traffic from the Gulf of Mexico across the Isthmus of Tehuantepec, a distance, I think, by rail of 200 miles, though the distance in a direct line is less than that. This shows that the enterprise of some of the business men—traffic men—has somewhat outstripped the enterprise of the United States Government.

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## THE PANAMA RAILROAD—AN HISTORICAL SKETCH.

JOSEPH E. MURPHY, M. W. S. E.

The problem of a trans-Isthmian link connecting the Atlantic and Pacific oceans, soon to be solved by the completion of the Panama Canal, has claimed the attention of the civilized world for nearly five centuries. At first the search for the strait that was universally believed to exist, and later, attempts to discover a suitable route for an artificial strait, called forth many expeditions, some of them ending disastrously. But, apparently, not until the end of the eighteenth century was any thought given to the construction of an Isthmian railroad.

A member of the society has recently loaned to the secretary, for the purposes of this paper, a collection of old notes and correspondence relating to the Panama Railroad, and also a copy of Harper's New Monthly Magazine for January, 1859, containing a brief history of the railroad and an account of a trip across the Isthmus. This account was written by "Oran," author of a series of articles on "Tropical Journeynings," pub-

lished in Harper's Monthly about that time. The name "Oran" is evidently the pen name of Fessenden N. Otis, who, in 1867, published a book containing a history of the Panama Railroad and various other matters of interest concerning the Central American states.

Accustomed as we are to present-day facilities for transportation across the continent, it is difficult to realize the tremendous importance of the Panama Railroad at the time it was built, and for many years after. Some years prior to the promotion of the railroad the treaty with Great Britain was signed, securing to the United States the rich territory of Oregon. The attention of settlers had been forcibly called to this territory through the long controversy over the northwestern boundary line. There were then but two routes for reaching this distant country—the overland route and the voyage around Cape Horn, either of them requiring months of time and involving many dangers.

In the year 1848, following the treaty with Mexico by which California was ceded to the United States, Congress saw the necessity for better communication with these newly acquired territories, and authorized contracts for the establishment of two mail steamship lines, the one running from New York and New Orleans to Chagres, and the other from Panama to California and Oregon. By the establishment of these lines the bulk of the Cape Horn travel was diverted to the Panama route. But the trip across the Isthmus, a matter of only fifty miles, was difficult and dangerous. It was necessary to proceed by native canoe or bonga up the Chagres River from Chagres to Gorgona or Cruces, and thence on mule-back to Panama. In addition to the fatigue and possible sickness incident to the trip across the Isthmus, there was constant danger from bandits in the hills west of Cruces. The very landing at Chagres was often attended by great danger. Ships were compelled to stand off in an open roadstead, and in rough weather lives were often lost in the transfer of passengers to the shore. This short link in the route to California and Oregon came to be more dreaded than all the rest of the journey. The demand for better transportation across the Isthmus became, therefore, urgent, and was met in a few years by the construction of the Panama Railroad.

It was impossible for the men of that time to foresee the developments that fifty years would bring forth, and it was then believed that the completion of this railroad was a final solution of the problem of coast to coast transportation.

But long prior to 1848 the construction of a railroad across the Isthmus had been agitated. The earliest reconnaissance of the Isthmus for the purpose of finding a railroad route was made by Charles Biddle, who had been commissioned by the United States Government to examine the different routes

adapted for inter-oceanic communication, and report on their value. He visited the Isthmus of Panama in the year 1835, and was so favorably impressed with this route that he did not carry his investigations further. When he returned to the United States in the year 1837 he brought with him an official copy of a decree issued by the government of New Granada, granting the right to build a railroad across the Isthmus of Panama. But his return found the country plunged in a financial crisis and the promotion of the railroad was not undertaken at that time.

In the year 1848, John L. Stephens, accompanied by J. L. Baldwin, a civil engineer, made an exploration of the proposed railroad route and found it entirely practicable. This exploration revealed a pass in the mountain range not more than 300 feet above sea level, and it was thus demonstrated that a railroad could be built without the use of excessive grades. Shortly after this a contract of a favorable nature was secured from the government of New Granada.

In the meantime, the mail steamship lines authorized by Congress in the year 1848 had been established, and there was needed only the construction of this short piece of railroad to complete one of the most important traffic routes in the world of that day. Conditions brought about by the acquisition of the new territories on the Pacific Coast, together with the shortening of the route to the Orient and the west coast of South America, seemed to the promoters to insure an ample return on the investment. But they little dreamed of the business that would be offered before even the construction of the road could be begun, for within a few months gold was discovered in California and the discovery was followed by a rush of gold seekers across the western plains, across the Isthmus, and around Cape Horn, that was to become one of the phenomenal events of history. For years after its completion, the Panama Railroad carried from 6,000 to 7,000 passengers per month each way, the homeward travel being almost as heavy as that in the opposite direction.

Following the exploration of the route by Stephens and Baldwin, a company was formed in the state of New York with a stock issue of one million dollars. In the year 1849 a detailed survey was undertaken under the direction of Col. G. W. Hughes, of the United States Topographical Corps. In the prosecution of this survey Mr. Baldwin located a summit gap thirty-seven feet lower than the one discovered by him the previous year. The road as located through this gap lay within the prism of the present Culebra cut.

A contract for the construction of the road was let in 1849 to George M. Totten and John C. Trautwine, both of whom had had previous experience in construction in the tropics. The terms of the contract were based on the assumption that labor

on the Isthmus was cheap and easy to secure. On account of the California transit, however, which in a few months had become of great importance, the opposite condition was found to exist. Following an explanation of this fact, Messrs. Totten and Trautwine were released by the company as contractors but retained as engineers.

The city of Panama was the only logical terminus for the road on the Pacific end, and, after a thorough exploration by Mr. Trautwine, it was determined to locate the Atlantic terminus on the island of Manzanilla, in Navy Bay, now known as the Bay of Limon. The settlement that grew up about the Atlantic terminus, now the city of Colon, was originally christened Aspinwall, in honor of William H. Aspinwall, the founder of the Pacific Steamship Line, and one of the leading spirits in the promotion of the Panama Railroad. Previous surveys had indicated that the Chagres River was navigable for vessels of light draft as far as Gorgona, and it was therefore planned to build first from Gorgona to Panama and operate this portion of the road in connection with steamboats plying between Chagres and Gorgona. Headquarters were established at Gorgona and surveys begun from that point toward Panama. Two vessels were sent to the Isthmus for this service, but it was soon discovered that only in time of flood could the Chagres River be navigated by other than the native canoes and bongoes. Headquarters were then moved to the island of Manzanilla and location across the tropical swamps toward Gatun was immediately begun.

The modest "breaking ground" is thus described by Oran: "Two American citizens, leaping, axe in hand, from a native canoe upon a wild and desolate island, their retinue consisting of half a dozen Indians, who clear the path with rude knives, strike their glittering axes into the nearest tree; the rapid blows reverberate from shore to shore, and the stately cocoa crashes upon the beach. Thus unostentatiously was announced the commencement of a railway, which from the interests and difficulties involved, might well be looked upon as one of the grandest and boldest enterprises ever attempted."

It is only necessary to state that the two American citizens engaged in this "unostentatious" proceeding were John C. Trautwine and J. L. Baldwin.

It would be hard to exaggerate the difficulties met and overcome in locating and building this railroad. Topography, climatic conditions, scarcity of labor, and the active antagonism of the natives engaged in the transit, all seemed to conspire for the defeat of the enterprise. Men less hardy and determined would have abandoned it at the outset. From the first, a large percentage of the force was disabled by sickness. A regular system of reliefs seems to have been established among the officers and engineers, one man working in the swamps until attacked by

fever, with the expectation that by the time his strength failed a substitute would have recovered sufficiently to take his place. Probably the most difficult portion of the work lay between the Atlantic terminus and Gatun, this portion being a swamp, under water the greater part of the year, and covered by a dense tropical jungle. With the exception of a narrow strip along the route of the transit, the topography of the Isthmus was practically unknown, and it was necessary to make extensive reconnaissance before selecting a route.

In the month of August, 1850, actual construction was begun from the Atlantic terminus toward Gatun. At about the same time supplies and machinery were received from the United States and taken to Gatun, the Chagres being navigable to that point. Construction was begun across the swamps to meet the work already in progress at the Atlantic terminus. The work was constantly hampered, and at times practically brought to a standstill, by sickness and by the desertion of large numbers of workmen to take service in the Transit, where better wages and an easier life were offered. It was necessary to bring in recruits constantly, mainly from Carthagena and Jamaica.

On the first day of October, 1851, a work train passed over the road as far as Gatun.

At about this time there came a crisis in the affairs of the company, when it looked as if the entire enterprise might be abandoned. The original stock subscription had been exhausted. The rating of the stock was low, and it seemed impossible to interest capital to the extent of further investment in a railroad, the ultimate completion of which was coming to be thought impracticable, if not impossible.

Then an unexpected thing occurred that was destined to turn the tide in favor of the railroad. In October, 1851, two steamships, the *Georgia* and the *Philadelphia*, arrived at Chagres with about one thousand passengers en route to California. Owing to the tempestuous weather it was impossible to make a landing at Chagres, and after several lives were lost in the attempt, the ships took refuge in Navy Bay. It was then proposed that the passengers should be transported over the railroad to Gatun, whence they could proceed in the usual way to Panama. At this time, naturally, there was no equipment for handling passengers, but after some delay a sufficient number of work cars were assembled at Navy Bay to take the passengers to Gatun. The fact that California passengers had been hauled over a portion of the Panama Railroad, when made known in New York, instantly restored confidence in the enterprise, and no great difficulty was experienced afterward in securing funds for carrying on the construction. Passenger equipment was secured and from that time passengers were regularly transported to the end of the completed road; first to Gatun, then to Bujio Soldado, then to Barbacoas, and then to Gorgona, as each

section of road was made ready for operation. Each successive step eliminated in great degree the hardships and dangers of the Transit.

The construction of a bridge over the Chagres at Barbacoas proved to be one of the most formidable features of the undertaking. Draining a large section of mountainous country, with the floods of torrential rains to carry off, this river is subject to sudden freshets, the water often rising as much as forty feet in a single night. When nearly completed, one span of the bridge was carried away, and as the working force employed on the bridge had been greatly reduced by sickness, and every portion of the work had cost more than the contract price, with this disaster the contractor abandoned the work. After considerable delay the company took the work in hand and completed it. With the exception of the delay caused by the construction of this bridge, work was pushed forward rapidly. The working force was recruited constantly by laborers brought from all parts of the world, but every steamer that brought recruits carried away on its return trip large numbers of workmen disabled by sickness.

The art of fighting tropical fevers was not so well understood then as now, and the effect of the climate was the one great difficulty for which there seemed to be no solution other than the constant substitution of fresh labor. At one time a thousand Chinese were brought in. Every provision possible, with the means at hand, was made for their comfort and well being. But after a few months many of them were stricken with fever. The entire colony developed a strange melancholia and mania for self destruction, and it was suddenly found necessary to transport such of them as were still living (about two hundred in number) back to China.

In January, 1854, the road was completed to the summit ridge at Culebra. At this time an additional force started construction north from Panama to meet the advancing work from Culebra. On the night of January 27, 1855, the two lines met, and at last the Panama Railroad was an accomplished feat. On the following day an engine passed from ocean to ocean, and the completion of this stupendous undertaking was announced to the world.

For several years following the opening of the railroad, work was continued vigorously. Cuts and embankments were widened, sidings and terminal facilities were constructed, and temporary structures generally were converted into permanent structures. When Oran visited the Isthmus, presumably in the year 1858, he found a well-built railroad with a service adequate to all needs. In the month of January, 1859, the construction account was closed, the total cost of the road to that date being eight million dollars. The gross earnings for the period were prac-

tically the same amount, and the net earnings about six million dollars.

By far the most interesting structure, both in an engineering and a historical way, is the plate girder bridge over the Chagres River. The girders were carried on stone abutments and piers built during the construction of the road. The spans were originally of wood. Chief Engineer Totten, in his report of 1855 to the Board of Directors, has the following to say in regard to this bridge: "The bridge over the River Chagres has one span of two hundred feet, and four spans of one hundred feet each. It stands forty feet above low water of the river. The abutments and piers are of cut stone, laid in cement. The superstructure is of yellow pine timber. The whole bridge is very substantial." Evidently the wooden spans were replaced by girders prior to 1858, for when Oran visited the Isthmus he found the Chagres spanned by a girder bridge. These girders were all in use until after the beginning of construction on the Panama Canal. Several years ago, under the direction of Mr. Hiram J. Slifer, then General Manager of the Panama Railroad, the stresses in these girders were figured, with the surprising result that they were found to be "so equally proportioned that the webs and all members had the same equal strain, even down to the rivets." Search has been made, but fruitlessly, for the name of the engineer capable of such design as this in the early 50's. But it is known that the girders were made at the West Point Foundry, across the Hudson from the West Point Military Academy. This foundry was a famous institution in early days. The first American locomotive intended for actual service was manufactured there, as well as the "Parrott" guns of the Civil War.

It has been said that for every tie in the Panama Railroad a human life was sacrificed. This, no doubt, is a gross exaggeration. In all, between 6,000 and 7,000 white men were employed in the construction of the road, and of these, according to the records, 293 died on the Isthmus. No record was kept of the mortality among other classes of labor, and the number of deaths will never be known, even approximately. But it is certain that untold thousands succumbed to tropical fevers made doubly malignant by the inevitable unsanitary conditions under which these men were compelled to live and work.

# CENTRIFUGAL PUMPS

WILLIAM R. WILEY, M. E.

*Presented January 19, 1910.*

On the very broad subject of centrifugal pumps, due to the abundance of material at command, it is necessary to limit this paper to certain points which bear on general features rather than on the detail and theory of design and construction.

The average engineer is not interested in the actual evolution of formulas of design, but rather in the scope and application of the pump to engineering problems.

In the past decade, the development of the centrifugal pump has been truly remarkable and in this country notable strides toward perfection have marked this period. At the present day it may be

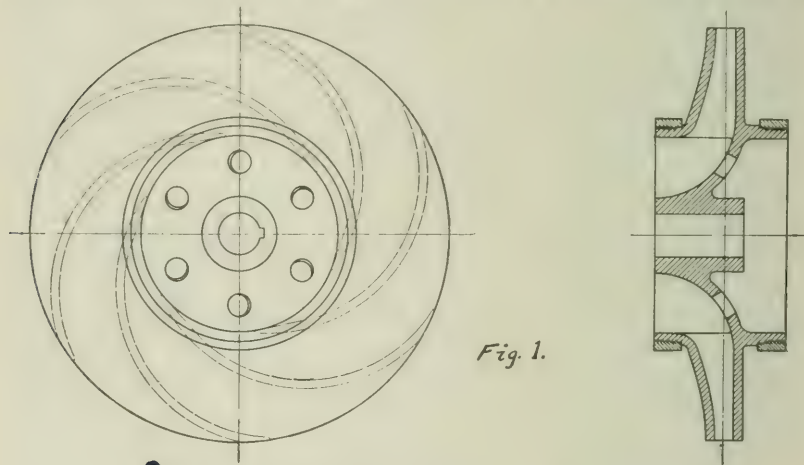


Fig. 1. Single Suction Enclosed Type Impeller.

truly stated that for every installation for which a reciprocating pump may be offered, a centrifugal pump can be built to perform the same service. The illustrations shown, may, to a certain degree, portray a special line of pumps, but the features as outlined therein, apply to the best manufacturing practice of the day, throughout the centrifugal field.

The first use for which the centrifugal pump found application, was for delivering varying quantities of water against low heads, and it is in this field to-day, that this type is far ahead of any other design.

Figure 1 shows a single suction impeller of the enclosed type. There are two general types of impellers or runners used in centrifugal pump design to-day, and these two types are shown opposed in Fig. 2. You will note that the walls A and B are lacking in the open impeller pump. The open impeller has only a limited application. It finds its best field in low lift pumps of single stage type,

and even on these low lifts the efficiency of the enclosed type more than counterbalances the increased cost of construction. There are certain classes of rough work such as are met in contracting where the open impeller pump presents the best solution.

In the further remarks reference is made to the closed impeller, as this type embodies the features of the most modern practice.

The actual design of the centrifugal pump presents many interesting problems, and the majority of data for said design are secured from results obtained on the testing floor. Test reports and experience have shown that the best results are obtained by the use of a velocity of eight to ten feet in the casing and through the pump. This velocity may be increased for high lifts per stage. With the velocity within the limits above stated, the best efficiencies are obtained and this velocity in itself determines the size of pump to be used for a certain capacity and also the range of adaptability of a given pump casing. With a certain size casing, reasonable results from the standpoint of efficiency can be obtained over a considerable variation of capacity. Due to commercial considerations, therefore, and the necessity of having standardized designs, each individual size of casing must be constructed for an average of the service which it must perform.

Referring to Fig. 1 there is shown an impeller of standard enclosed type. It is not the intention to describe the design of this part in detail. The velocities through the impeller and the design of same, to secure rated capacity against the proper head at a given speed are largely determined from data secured on the testing floor and from theoretical calculations in connection with the actual results obtained. The design should be such that the efficiency will be maximum at the capacity of the pump when operating against a given head. The amount of work that can be performed by a single impeller is limited. Past experience shows that it is inadvisable to design a single impeller for a lift of more than 140 ft. For lifts up to 140 ft. the work may be efficiently performed with a single impeller, and to this class of pumps your attention is invited.

Figure 3 shows a section through a single stage pump of the single suction type. The water enters the pump at A and is drawn into the impeller B. Here the water is received by the revolving vanes of the impeller, and is discharged into the water chamber C. The water leaves the tip of the impeller at high velocity, which is transformed into pressure through the vortex chamber, and the high velocity of peripheral discharge is retarded to conform to the velocity in the pump shell or volute. The passages through the impeller and casing should be smooth and clean, so as to reduce friction losses and increase the efficiency of the pump. The impeller B has two rings mounted on the same, running on machined surfaces in the casing. The ring E prevents leakage losses. The impeller creates a pressure  $P$  and a portion of the pressure exists at ring E. On the other side of the ring there is a suction pressure representing the amount of lift on the pump. Due to the difference of pressures there

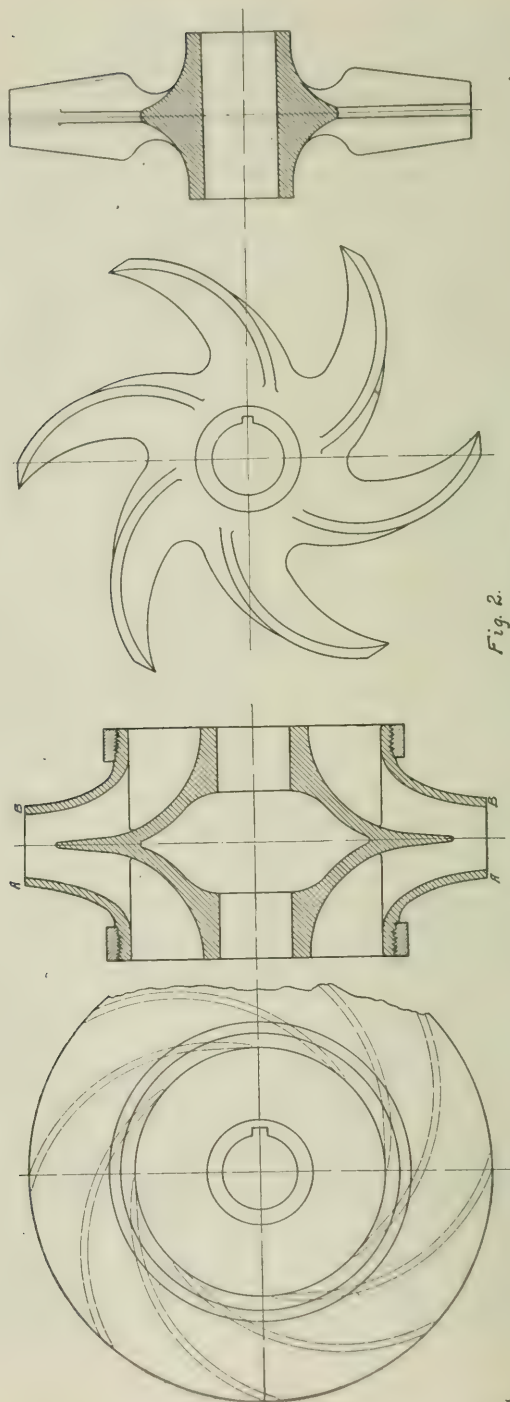
*Fig. 2.*

Fig. 2. Enclosed and Open Type Impellers.

FIG. 3  
SINGLE SUCTION VOLUTE  
PUMP

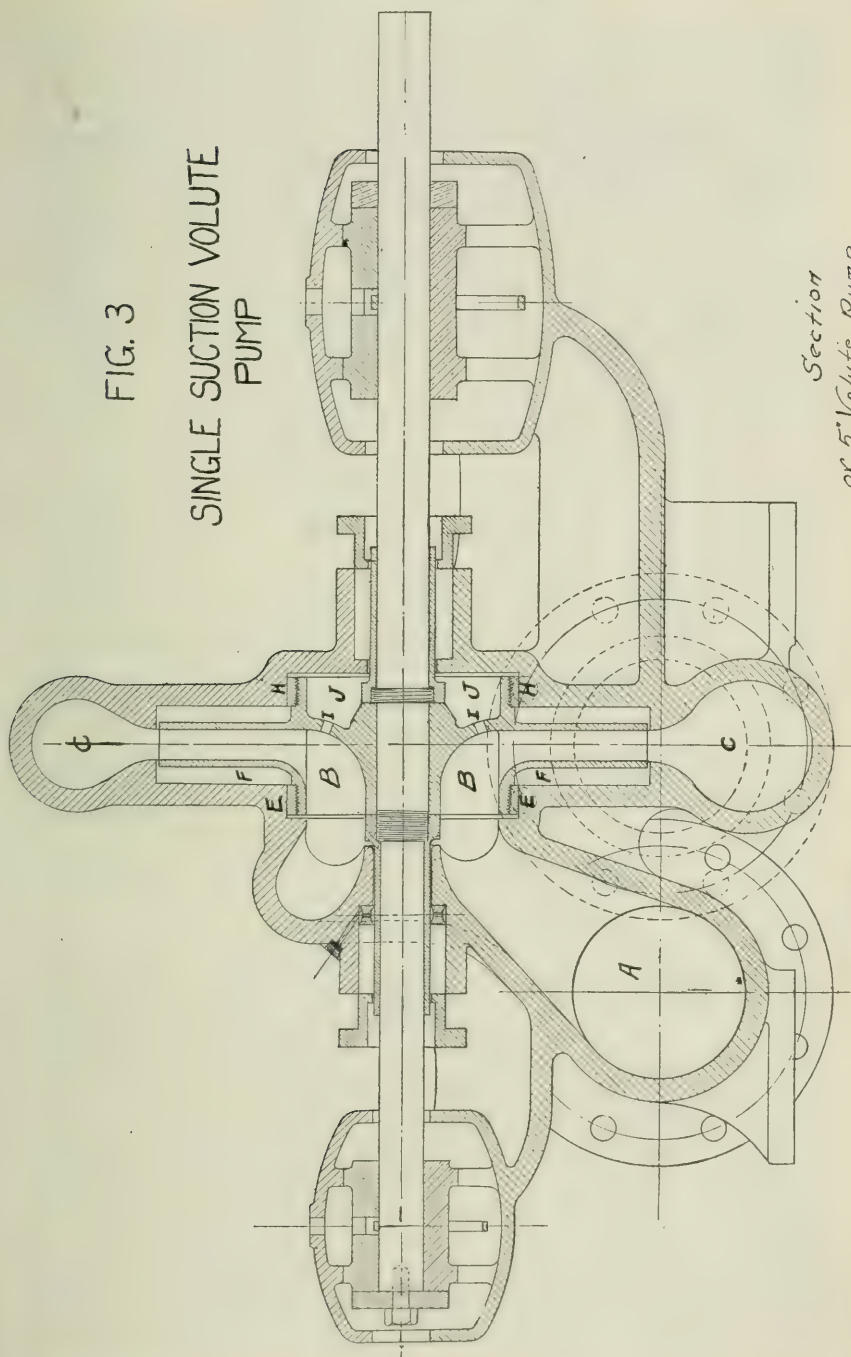


Fig. 3. Single Suction, One Stage Centrifugal Pump.

is a tendency for the water to flow from chamber F into the suction, but this is overcome by introducing the ring E, which prevents such leakage. The other ring H is mounted on the impeller to help balance the same against end thrust. The ring H is the same diameter as E. The holes I are so drilled that the pressure in chamber J is about the same as the suction pressure. The same pressures existing inside these rings results in an easy balance. On the two sides of the impeller outside of rings the pressure acts on both sides of the impeller on equal areas. These areas are equal to the annular space lying between the impeller diameter and the rings E and H respectively. The pressures being equal on equal areas the resulting thrusts are balanced. Thus the forces within and without the rings E and H of the impeller are balanced, and the end thrust resulting, is almost negligible.

In Fig. 4 is shown a single suction impeller without the ring. You

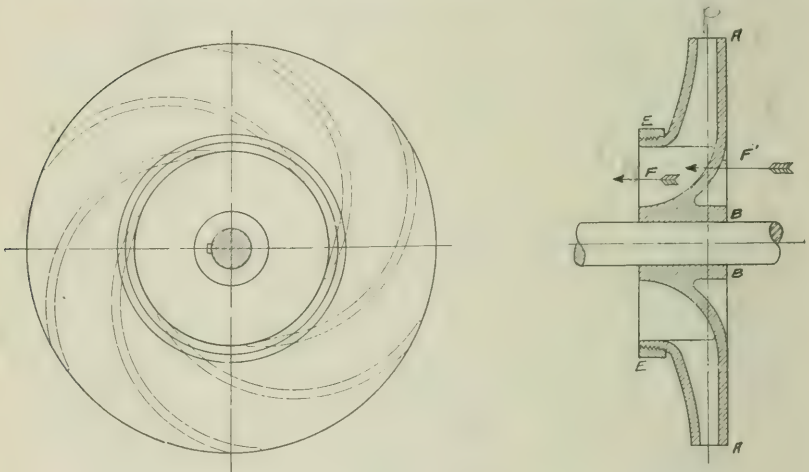


Fig. 4. Single Suction Impeller.

will note that the pressure  $P$  acts on the larger area on back of impeller from A to B. On the opposite side,  $P$  acts only on the area from A to E, the diameter of ring. Therefore, due to pressure  $P$ , there is an unbalanced thrust equal to  $P$  times the area of the annular ring lying between B and E, or the area of ring and diameter of shaft. This creates an end thrust in line  $F'$ , and to this thrust is added that due to suction pressure times the area of ring E, which is shown by F and acts in the same direction as  $F'$ . Therefore, the impeller is in an unbalanced condition, which unbalanced condition must be remedied by introduction of ring H, as shown on Fig. 3, or by some other arrangement designed to secure the same effect.

The design of single suction pump shown above is applicable to many classes of low lift work and is subject to slight variations for

different classes of service. The design as shown represents a pump as built for high efficiency handling clear water.

In Fig. 5 is shown a single stage double suction volute pump. In this pump the incoming suction column is divided into two separate streams, which enter the impeller on opposite sides and are discharged into a common vortex chamber. By this arrangement per-

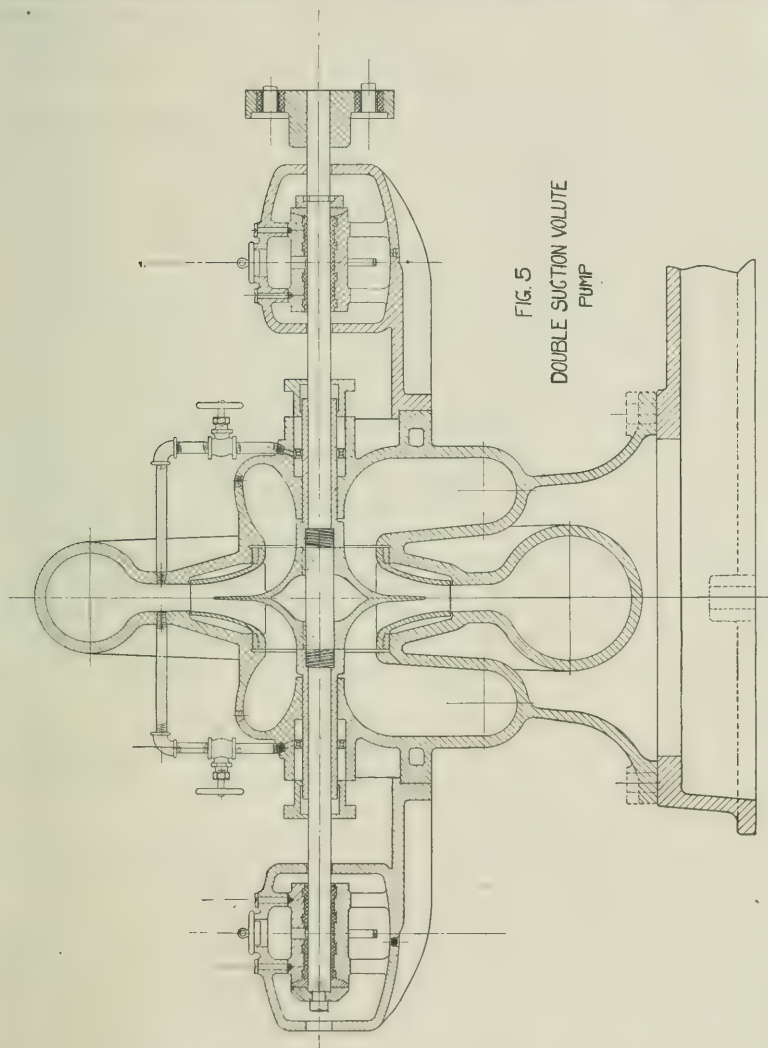


Fig. 5. Double Suction Single Stage Volute Pump.

fect balance is secured. This design automatically balances the thrust as equivalent operations are performed on both sides of the central plane of the pump. This balance is almost perfect and it is

only necessary to place collars at the ends of the bearing journals to keep the shaft and impeller in a central position.

This pump is very satisfactory for heads up to 140 ft., and some makers design pumps of this type for even higher lifts. The type is especially adapted for use with steam turbine drive, due to the high speed which is available.

As a general rule, for lifts over 140 ft. to 150 ft. the best practice is to use two or more impellers in series, as shown in Fig. 6, which represents a pump of the three stage type, having three impellers mounted in series on one continuous shaft.

The water from the suction enters A and is discharged from the impeller into the diffusion ring C. Figure 7 shows one of these diffusion rings. The tips of the vanes at E are designed so that the angle of same lies in the same direction as the resultant velocity of the water leaving the impeller. These vanes receive the water at high velocity and gradually transform this velocity into pressure. The water leaves this vane with decreased velocity, and increased pressure and this reduction has been obtained in an efficient manner through the medium of the diffusion vanes, which have transformed this velocity, with reduction of hydraulic and eddy losses to a minimum. The water leaves the diffusion ring at C and enters the return chamber T, which guides the water at low velocity, but with a pressure due to the first impeller to the suction opening of the second impeller, where the water is received under pressure and again boosted in velocity. This velocity is in turn transformed into an increased pressure, by a second set of diffusion vanes. The work performed in each impeller and the pressures produced by same are practically equal and all impellers and diffusion rings are of the same design and construction. The number of impellers used, or in other words, the number of stages in the pump is determined by the total lift against which the unit must operate, and the economical lift per stage at the available speed.

The balancing of a multi-stage pump follows similar lines to that of a single stage pump. The unbalanced pressures are the same on each impeller, and various means are used by different manufacturers to eliminate this thrust.

In order to keep this adjustment independent of too fine a degree and to retain revolving parts in accurate alignment, a thrust bearing is usually furnished of the marine or roller type.

A characteristic diagram obtained from the test of a 12-in. double suction pump is shown in Fig. 8. This pump was driven by a 200 hp. direct current motor at a constant speed of 850 r. p. m. Curve No. 1 shows the heads obtained at various capacities. Curve No. 2 the efficiencies at these capacities, and curve No. 3 the brake horse power required by the pump at various capacities. These curves show the performance of the pump from zero delivery to delivery of about 4400 gal. per. min. The test from which data for laying out Fig. 8 were obtained is shown in tabulated form. The capacity

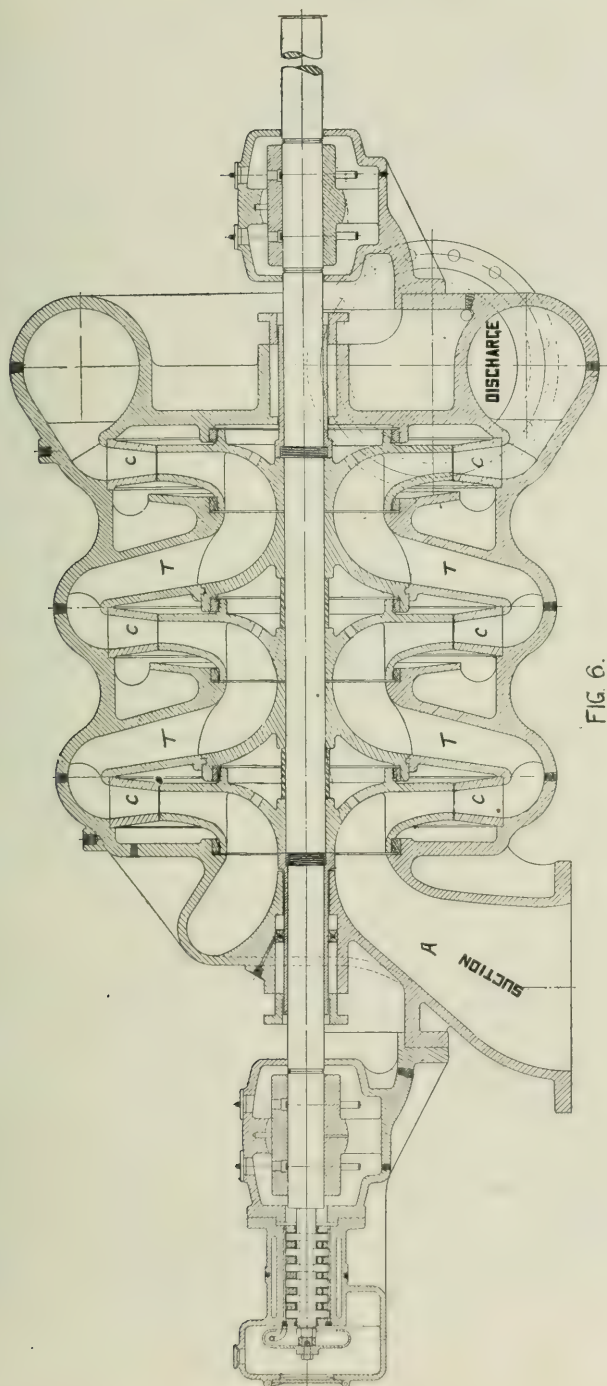


FIG. 6.

**THREE STAGE HORIZONTAL TURBINE PUMP.**

Fig. 6. Three Stage Pump for High Service.

was measured by means of a nozzle and pitot tube, the pitot tube connecting to a water column indicating the velocity of flow. These nozzles are fully checked and verified by use of wier comparison and the accuracy of the readings obtained is remarkable. For a given size of nozzle based on calculation and test of the nozzles a constant is obtained. This constant multiplied by the square root of the head recorded on the water column gives the capacity in gallons per minute. This method of measurement is convenient, accurate, and flexible. In determining the total head at any one point the method used is that prevalent among most manufacturing concerns. The discharge pressure is read in pounds gauge. The suction condition is ascertained by use of a mercury U tube or its equivalent. To the sum of these two readings expressed in feet is added the dis-

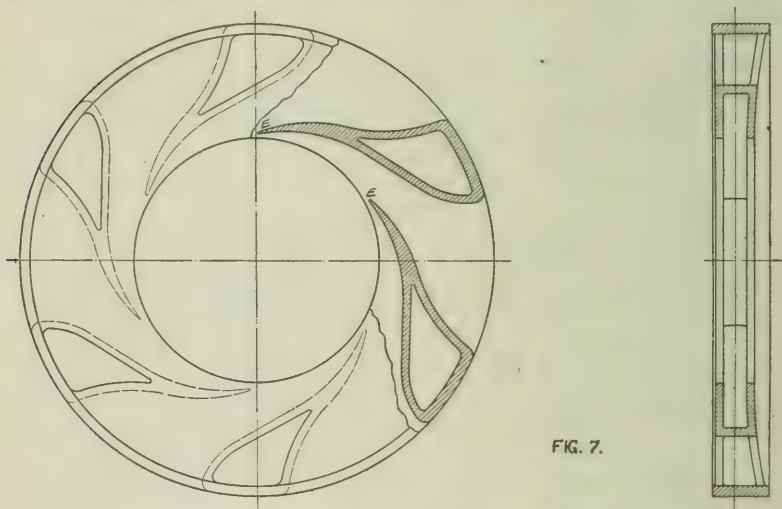


Fig. 7. Diffusion Ring for Three Stage Pump.

tance between the center lines of the discharge and vacuum gauges used. For all practical purposes this gives the total head. Having obtained these two readings the water hp. or hp. output is easily figured. The electrical readings are obtained by the use of voltmeter and ammeter and from the electrical hp. obtained the brake hp. and finally the efficiency of the pump are calculated. You will note that at zero delivery 60 hp. is required for driving. This is consumed in friction between the impeller and water in the pump case. As there is no water delivered at this condition, this work must be transformed into heat. Therefore, if a centrifugal pump is operated for some time with the discharge valve closed, the water in the casing will be heated to a dangerous point. As the head on the pump is reduced the capacity increases. The 12-in. pump shown was designed for a delivery of 3600 gal. per min. against a total head of 140 ft. By

referring to the characteristic it is noted that by following the abscissa for 140 ft. to the curve for head and capacity, we obtain a capacity of 3750 gal. per min. with an efficiency of 74%, and for these conditions 190 hp. is required for driving. At this point, which is the operating condition of the pump, the efficiency curve should reach its maximum. The general form of this curve is such that efficiency of over 60% is obtained throughout a range of capacity from 2000 to 4300 gal. per min. Another important feature shown on this sheet is the overload characteristic. As the head is reduced below 140 ft., the efficiency falls off rapidly. This is due to the fact that the velocity becomes too high for efficient operation, and at this increased velocity the hydraulic losses are higher. In some centrifugals, when the head is reduced considerably below the normal operating head,

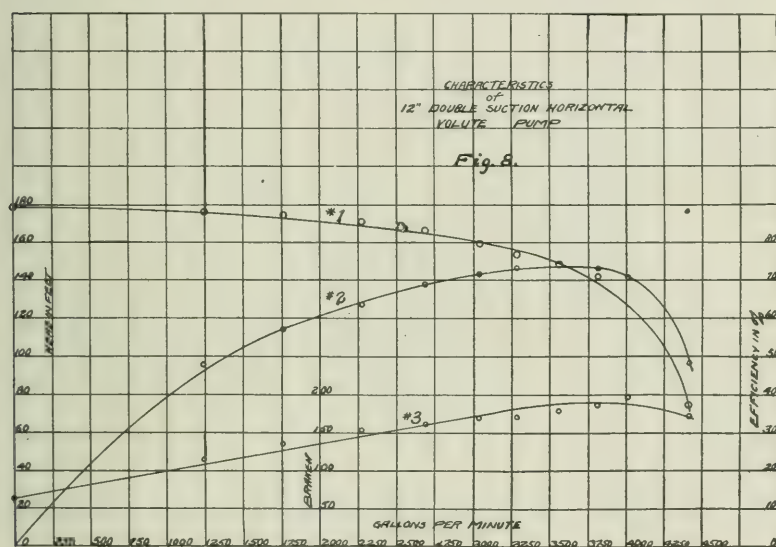


Fig. 8. Curves from Tests of 12-inch Double Suction Pump.

an overload is thrown on the motor. This feature should be obviated in the design. It will be noted that the hp. curve reaches its maximum in Fig. 8, at about 140 ft. head with a capacity of 3750 gal. per min. When the head is lowered still further, the form of the hp. curve is such that the hp. required is less, and as a result the motor is not overloaded at the reduced head. Throughout the whole range of head, from shut-off or zero capacity, to head reduced below normal, it is impossible to overload the driving unit. If the discharge line on the pump were suddenly closed no damage would result and a maximum pressure, the equivalent of 180 ft. would be generated. If the column pipe should burst, the delivery would increase, but the motor would in no way be overloaded. The above

sheet shows a typical best result obtained from a constant speed run with the main features and general formation of curves arranged so as to secure the best results from every standpoint.

Figure 9 shows the results obtained with variable speeds, from tests of an 8-in. six-stage pump, operating at speeds between 760 and 1150 r. p. m. Each curve shows results obtained from a constant speed run at the speed specified. We will assume that this pump was designed for a capacity of 700 gal. per min. against a head of from 180 to 570 ft. When operating at 760 r. p. m., the pump delivered 700 gal. per min. under 180 ft. head, with an efficiency of 58%. Increase of speed increases the peripheral velocity of the impellers and the head at which they will discharge a

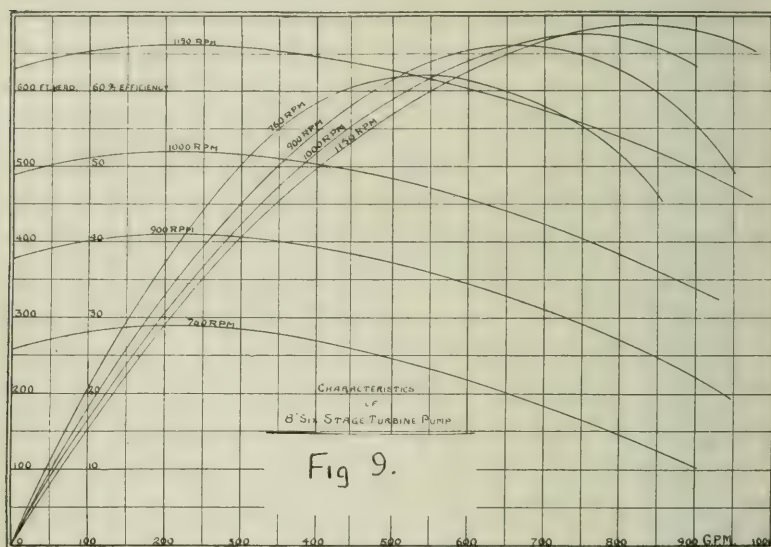


Fig. 9. Curves from Tests of 8-inch 6-Stage Pump.

given volume. At 900 r. p. m., a delivery of 700 gal. per min. against 310 ft. head with 66% efficiency is obtained. The point of maximum efficiency changes with the speed. At 1150 r. p. m., the maximum condition required is reached and a delivery of 700 gal. per min. against 570 ft. head with 67% efficiency is obtained. It is to be noted that the only way to obtain varying capacity against constant head, or varying head with constant capacity, or both, with a centrifugal pump *economically*, is by change of speed. With constant speed motors, as per characteristic sheet Fig. 8, a certain performance results and the pump will discharge against a fixed head at a fixed speed only one delivery rate.

The efficiency, based on hp. input and hp. output, varies with the size of the pump. This is the principal controlling feature. With

small pumps, say 2 in., the efficiencies obtained are rather unreliable, but a good average is 45%. As the size of the pump increases the efficiency increases until with an 8-in. pump, efficiencies of 68% to 70% are obtained. After this point, the efficiency does not increase so rapidly. The best efficiency obtained by the writer was from a 24-in. pump built for irrigation service for the United States Government, having a capacity of 13,500 gal. per min. When operating against a head of 50 ft. at 650 r. p. m. this pump showed an efficiency of 83%. About a year after the apparatus had been placed in operation, tests were conducted which showed that this efficiency had been maintained and against the rated head the pump showed an efficiency of 80%. This degree of economy is not obtainable in all instances, however, and most guarantees of efficiencies above 80% are not obtainable commercially except under special conditions.

The next point to be considered briefly, is the advantage of centrifugal design over the older reciprocating type. Taking average figures, it may be stated, that the centrifugal pump costs half as much and weighs one-third as much as a reciprocating pump for the same conditions. For low head work, this proportion is greater and in favor of the centrifugal, while for the higher heads, the cost of the two types more nearly coincide.

Next the question of simplicity. Here the centrifugal pump has a marked advantage. There are no valves or springs and only one simple rotating element. The shafting is supported in ring oiled bearings, cutting down items of attendance. Having about one-third the tonnage, the ease of erection and transportation is marked.

No pump adapts itself to different types of drive with the flexibility of the centrifugal pump. Direct connected, this pump may be driven by electric motor, either A. C. or D. C. or by a steam turbine, and for low heads, by a steam engine, gasoline engine and water turbine. Belted, it may be connected to line shafting, a steam or gasoline engine and may also be geared or driven from silent chain. This flexibility renders the design applicable to the various types of standard prime movers.

One of the latest developments is the steam turbine driven centrifugal, notably for boiler feed service. Figure 10 shows a centrifugal boiler feed pump as designed to deliver 1000 gal. per min. against a pressure of 300 lb. gauge. This particular pump was driven by a steam turbine at 1650 r. p. m., the most economical speed for the turbine used. This pump possesses many advantageous features. The even flow obtained is distinctly desirable as compared with the intermittent flow obtained from a reciprocating pump. By means of an automatic balanced throttle valve, the speed of turbine and delivery of pump can be regulated so as to maintain the water in the boilers at a constant level. The governor on the steam turbine itself, can be set so that the turbine cannot operate beyond a certain speed, which speed will limit the pressure generated by the pump itself. This feature renders it impossible to throw dangerous shocks

on the pipe line. The steam turbine driven boiler feed pump is not as economical in consumption of steam (in most instances) as the ordinary direct acting pump, but in many cases the lack of economy is more than counterbalanced by the features above mentioned, and the conditions of the installation. In many power stations there is not sufficient exhaust steam to properly heat the feed water supply, as all the main units are operating condensing. Under these conditions the turbine driving the boiler feed pump is run non-condensing and the exhaust from the steam turbine is piped to the feed water heater. By this arrangement the over all economy obtained is in line with the best practice and the cost of installation, maintenance and attendance is reduced. In both prime mover and pump, we revert to the principle of simple rotary motion with its inherent simplicity.

In connection with this subject, might be mentioned the motor or

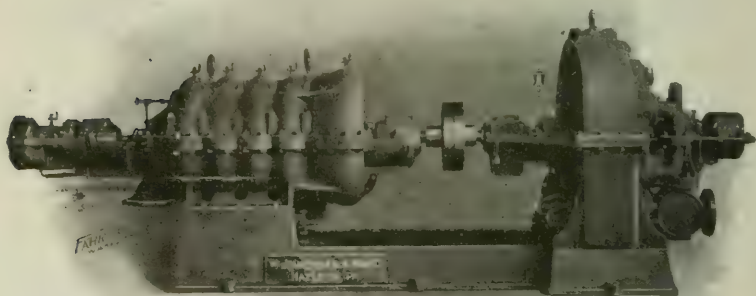


Fig. 10.

8 in.—Five Stage Centrifugal Boiler Feed Pump. 1,000 gal. per min.; 700 ft. head at 1,650 rev. per min.

turbine driven circulating pump, as used in connection with the barometric or jet condenser. A centrifugal pump, with a barometric condenser, is an ideal combination for central power station work. The centrifugal is designed to deliver a small portion of its water against a high head. After the vacuum is formed in the condenser cone this head is reduced and the pump is designed to operate economically at this running head with the delivery necessary. At both conditions of head the pump performs its service at constant speed.

The broadest field for the centrifugal pump to-day is for irrigation purposes. In this service the volute pump generally used costs less and is more economical than any other type. The capacity required in this service ranges from 1000 to 100,000 gal. per min. and the heads are usually under 50 ft. Standard designs are perfected

by various companies within the capacities above mentioned, suitable for direct connection, or belt driven, by motors or steam power.

For mine service the centrifugal pump is coming more into prominence. Due to the light weight of the parts in contact with the fluid handled, it is possible to construct the same of non-corrosive metal when desired. Very often the water to be handled in mine work is acidulous, and by the use of a good grade of acid resisting bronze, it becomes practical to build a very durable pump at a moderate price. Many mines are being electrified, which broadens the field of application. The writer is in touch with a large number of installations of this character, electric motor driven for lifts up to 600 ft. and in each instance the service performed is satisfactory from every standpoint.

Criticism is sometimes heard in regard to the operation of the centrifugal pump. This is bound to be true with any new machine. The average operator is not familiar with the pump, either from the point of mechanical construction or performance. The pump in itself is extremely simple and 90% of the trouble encountered is due to inexperience on the part of the operator. The reciprocating pump has had a more gradual development and the public has been educated in regard to its features and operation. To secure perfect operation and understanding of the centrifugal pump, we must, to a certain degree, educate the customer.

Briefly, the following points should be observed in operating and installing centrifugal pumps. Regardless of the size of suction and discharge on the pump, suction and discharge pipes should be of such size that the maximum velocity of the water will not exceed 200 ft. per minute, and the use of long sweep ell's is recommended. The pump should be protected against water hammer on high lift. No centrifugal pump will operate unless fully primed before starting. Unless the suction water flows to the pump under head, it is necessary to employ some method to secure a "primed" condition, as the centrifugal pump will not take up its water under suction lift as is the case in other types, such as plunger pumps. This priming may be secured by various means usually depending on local conditions surrounding the installation. Every centrifugal pump when sold, is sold for a certain duty. If this head or duty is changed, the result will usually be a loss of efficiency. A study of the characteristic sheet Fig. 8 will show the reason for this statement.

The field of application of the centrifugal pump is limited by practical considerations. This type has been built for lifts of over 1000 ft., but the general opinion is that this construction does not represent the best practice. The writer's experience has been that for lifts over 700 ft. a reciprocating pump may be built which will operate more economically and be more durable than the centrifugal pump. In these high lift centrifugals it is necessary to place a number of impellers in series, say eight to ten, and the construction becomes bulky and expensive.

## TEST DATA FROM 12 IN. DOUBLE SUCTION VOLUTE PUMP.

No. of Reading	Suc. Gauge Inches Mercury	Dis Gauge lbs.	Head on Nozzle	R. P. M.	Volts	Amps.	Elec. H. P.	Brake H. P.	Water H. P.	Total Head Feet	Gals. Per Min.	Pump Eff. %	Motor Eff. %
1	14.0	57.5	2.45	850	230	640	197.0	180.3	133.5	148.9	3560	74.0	91.5
2	12.5	60.0	2.08	850	230	615	189.5	173.0	126.5	152.9	3285	73.2	91.3
3	11.3	63.5	1.75	850	232	600	186.5	170.0	122.0	159.6	3040	71.8	91.2
4	10.8	66.5	1.39	850	230	580	179.0	162.9	112.2	166.0	2685	69.0	91.1
5	8.8	69.5	1.00	850	234	540	169.5	154.2	98.0	170.7	2275	63.5	91.0
6	7.0	72.0	0.6	850	234	480	150.5	136.0	77.5	174.4	1765	57.0	90.5
7	5.2	74.5	0.3	850	234	410	128.5	115.2	55.7	177.2	1245	48.0	89.7
8	2.2	76.0	0.0	850	242	225	73.0	60.6	0.0	178.2	0	0.0	83.0
9	13.0	55.5	2.8	850	230	670	206.5	189.0	137.4	143.1	3810	72.7	91.5
10	14.0	53.5	3.1	850	228	710	217.0	198.9	141.0	139.7	4010	71.0	91.6
11	15.8	24.5	3.75	850	226	620	188.0	171.9	83.2	74.9	4410	48.4	91.4

Size of Nozzle, 10<sup>3</sup>/<sub>4</sub> in. dia.

Constant of Nozzle, 2255.

No. of Gauges used, 2.

Distance between Gauges, 0.5 ft.

Right here in Chicago is a field that I would like to speak of, and that is for the centrifugal fire pump. I have a little sheet which I received today, covering a test of a pump of this character. This particular pump is placed in the basement of one of your large buildings for operation in connection with the sprinkler system for fire protection. The pump was designed for a capacity of 1,000 gal. per min. against 150 to 160 lb. pressure, operating in connection with a direct current motor at a speed of 1,400 rev. per min. The ideal proposition about a centrifugal fire pump, motor-driven, is that when the pump is not in operation there is no expense for upkeep, but it is there ready to do business should a fire occur; there are absolutely no overhead charges, and even in case of fire the charge for the electric current is small. This particular pump, according to the report which I have here, showed, at the designed conditions of 1,000 gal. per min. against about 150 lb. pressure, an efficiency of  $68\frac{1}{2}\%$ . Of course, in the fire-pump the efficiency does not enter into the question so greatly because the apparatus is not in continuous operation. In addition to the cost of maintenance of this pump, there is the question of initial cost. The apparatus is there ready to run when it is wanted and it will cost, I should guess, about one-half of what a steam pump would cost for the same conditions, or any type of power-driven pump of the reciprocating type, and it occupies about one-third the floor space. Both these features are very important. Floor space means money, and if you can get the machine to do the work at one-half the cost and space, why not use it?

#### DISCUSSION.

*President Alvord:* I am sure we have all been much interested in this practical talk on centrifugal pumps. Centrifugal pumps are coming into use very rapidly and the field for them is constantly growing. In water supplies, centrifugal pumps are being introduced for large water-works stations, often steam turbine driven, and are found to be useful fire-pumps in cases where economy is not the highest consideration. We are often looking for a pump of low first cost which does not easily get out of order, for emergency use, and the centrifugal pump seems to fill this want to a very large degree.

*Prof. A. N. Talbot, M. W. S. E. (by letter):* The paper on centrifugal pumps would have more value in determining the scope and application of the pump to engineering problems if further data had been supplied. Even if the average engineer is not interested in the actual evolution of formulas of design, he is entitled to receive the information which will enable him to judge of the suitability of the pump to do a given work and to determine the relation between speed, head, discharge, etc. For example, if the diameter of the runner were given for the two

pump tests mentioned, the reader would be able to make an estimate of the speeds required for different heads, and this information would make the remainder of the data more useful.

The centrifugal pump is an excellent machine, applicable to many conditions. Contrary to general belief, it will give a wide range of discharge and a wide range of heads with a relatively small range of efficiency, provided the right speed for the desired head and discharge is maintained. The disadvantage of the pump is that small changes in speed will make a considerable difference in discharge, and this is troublesome where the speed of the pump may not be varied to suit the special conditions, and where the amount of water the pump is discharging cannot readily be determined. A constant speed motor is not suited for driving a centrifugal pump. In a way, tests made at a constant speed may mislead the engineer not fully versed in the principles governing such pumps. Possibly to this may be attributed such statements as that a change in head or duty will involve a loss in efficiency. To improper speed may be attributed many of the objections to centrifugal pumps. To be generally useful, a test should include runs with a range of head at approximately the same number of gallons per minute discharged.

The writer would like to ask if any reason is known for the low efficiency in No. 11 in the test of the 12-in. pump. That the velocity is too high for efficient operation and that, therefore, the hydraulic losses are higher, is hardly a satisfactory explanation. The change from No. 10 is too radical to be in keeping with the rest of the tests or with the results found with centrifugal pumps generally.

*Mr. Wiley:* In regard to point No. 11, I covered this briefly when I stated that when the capacity increased beyond a certain point, the losses in the suction head became so great that atmospheric pressure was not sufficient to create enough energy to force any more water through the suction head. The impeller is designed for efficient operation at 3,600. It has to be designed for a velocity of 10 or 12 ft., or thereabouts, for reasons of efficiency. This capacity of 3,600 gal. per min. is practically the maximum which this suction head and casing will handle. When the capacity is increased over this amount, the losses build up rapidly and result in a sharp drop in the curve.

If this same 12 in. pump was designed for a capacity of 3,000 gal. per min., the breakdown point, as you might call it, in that curve, would not come so close to the rated capacity of the pump. In other words, the suction head will permit a greater variation or increase in the capacity before it would refuse to pass any more water. The vortex chamber and the discharge chamber would also permit the increase, and the impeller under commercial conditions, because we have to use a standard size, would have a lower velocity than for the higher capacity of 3,600

gal. per min. So this test shows the design of that pump for practically the maximum conditions, and the breakdown point in the curve is more rapid than it would be for a pump designed for somewhat lower capacity, but using the same casing.

*Mr. J. H. Warder*, M. W. S. E.: I would like to inquire if you make a difference in the size of the runners for one standard casing, to suit different conditions?

*Mr. Wiley*: Yes, we do.

*Mr. Warder*: You can more readily vary the diameter of the runner than you can the dimensions of the casing, I suppose.

*Mr. Wiley*: Yes. For instance, the size of the suction opening will be fixed. In this 12 in. pump we have what we call a filling ring that is machined into the casing and is variable. If we have a 14 in. impeller, there would be one size of filling ring, and for an 18 in. impeller there would be another size filling ring. It is not necessary to change the casing pattern. It does not change the impeller suction opening unless, for instance, we had to operate against a low head at high speed for steam turbine drive. With a 12 in. pump, under these conditions, we would have to reduce the impeller diameter all that it was possible, and to increase the speed of the turbine engine so that we could secure economy from the steam end. In that case we would in all probability reduce our suction opening in the impeller itself but not in the casing. For the different diameters of impellers the casing is the same, with simply a filling ring between.

In the case of Fig. 5 you will note there is a certain size impeller. This could be made larger, as there are pieces on the pattern which are movable. The sides of the pattern inside the volute are loose, both on the outside and inside, making them adjustable to different diameters by simply slipping out a couple of pieces in the pattern. The casing on Fig. 5 is machined only where the impeller ring runs in the casing and where the shaft goes through the stuffing box.

*Mr. Charles W. Naylor*, M. W. S. E.: Will the centrifugal pump for boiler feed work with hot water fed to the pump?

*Mr. Wiley*: There is absolutely no objection to feeding hot water to a centrifugal pump for boiler feed service. In fact, practically all the centrifugal boiler feed pumps in service today are pumping water of a temperature up to 210 deg. F. and others up to 212 deg. F. There is no reciprocating motion, but simply a continuous flow of fluid in the pump. Of course, with water 200 to 210 deg. F. there can be absolutely no suction lift on the pump. The water must flow to the pump under a head. If the feed water heater, where the water usually comes from, is close to the pump, a head of about 6 or 7 ft. is sufficient, this head being necessary that the water may not vaporize in the suction of the pump. If there is sufficient head, all that head has to do is simply to procure a flow into the suction opening of the pump,

so that there is no suction pressure exerted at the suction opening of the impeller. Otherwise, if there is a suction pressure the hot water will vaporize. Having secured this condition for the centrifugal boiler feed pump, we design the impellers and diffusion rings of bronze, so that there may be no pitting action due to the hot water. I have taken apart pumps that have been in operation for a year and a half and found that there had been absolutely no pitting action; this construction is similar to a standard boiler-feed reciprocating pump which is bronze fitted. The impeller and working parts are built of bronze, and as far as wear and performance of the pump go the hot water has little or no effect on them. The running parts for boiler feed service are sometimes designed with slightly greater clearance, because there is a certain amount of expansion of the parts due to the temperature of the hot water. But the only point in the handling of hot water where the construction differs is the use of bronze in the impellers and working parts, and the necessity of having a head on the suction. The head on the suction also obviates the necessity of priming the pump. It is always ready to run because it is always full of water.

*A Member:* Is that necessary for a steam pump?

*Mr. Wiley:* If the water has a temperature of 210 deg. F., yes. If you have a long pipe running from the feed water heater to the pump, it has to have sufficient head to put the water into the pump, so that there is no suction lift. If you have enough suction to vaporize the hot water, it will vaporize in a steam pump; it will pump even if it does vaporize, to a certain extent. But with a centrifugal pump, if you once get vapor in the pump, it will not pump water. A head of 6 or 7 ft. does away with that difficulty. The boiler-feed pump is generally used in connection with an open feed water heater, which relieves itself of its vapor usually through an open vent at the top of the heater.

*A Member:* A leak valve?

*Mr. Wiley:* Yes; just to let the vapor escape at the top.

*Mr. Babcock:* I would like to ask if there is a better efficiency obtained in lowering the capacity of a pump by decreasing the speed for constant head, thereby decreasing the flow rather than throttling the pump outlet, which has the effect, of course, of increasing the discharge head and decreasing the flow.

*Mr. Wiley:* Under most conditions, yes. For instance, if you mean the pump was designed for a given set of conditions, if you wanted to reduce the head.

*Mr. Babcock:* No, reduce the volume, but with the same head.

*Mr. Wiley:* Whether it would be more efficient to slow up your prime mover or throttle on your head? It would be more efficient to slow up your prime mover.

*Mr. Babcock:* How much would the efficiency drop off the

volume? Does it drop off as fast as reducing the head for constant speed?

*Mr. Wiley:* I will show you. Refer to Fig. 9, showing variable speed characteristic.

*Mr. Babcock:* That is variable head, is it not?

*Mr. Wiley:* You will obtain the same thing with variable capacity. For instance, suppose you run a curve in between those two speeds of 1,150 and 1,000 rev. per min. In one place you get capacity against head, and in the other a lower capacity; with the same head.

*Mr. Babcock:* I see.

*Mr. Wiley:* With reduced speed the maximum point of efficiency comes in further on capacity abscissa as you reduce the speed.

*President Alvord:* One of the great difficulties with the centrifugal pump has been the lack of information among the engineering body in general. The manufacturers of the centrifugal pump have made a great many costly experiments in the last ten years, but for obvious reasons they are not published, and therefore the general body of the profession has not had the advantage of studying them. The University of Wisconsin has established an excellent laboratory under Professor D. W. Mead, and has done considerable during the last few years in studying centrifugal pumps, and has placed this information where it is available for all. We have with us tonight Mr. Clinton B. Stewart, who has been in charge of these experiments, and I think we will be interested in having him tell something of the work which this laboratory has done the past year.

*Mr. Clinton B. Stewart, M. W. S. E.:* Before coming to the platform I wish to ask Mr. Wiley in regard to the efficiency of the small unit. He gave the impression, to my mind, that the low efficiency of the small pump was due entirely to fluid friction. It seems to me there is another element which perhaps should be taken into account, and that is what is ordinarily spoken of as the stand-by loss or, in the case of small units, the large loss running light in proportion to any possible output of the machine. Take any piece of machinery of a small unit; judging from my experience its efficiency will always be smaller than the efficiency of the same character of machinery in larger sized units. It seems to me that might account for the large reduction in efficiency of the small unit as well as fluid friction.

*Mr. Wiley:* As I understand it, the statement is that, in addition to fluid friction, there are certain other factors entering in to reduce the efficiency of small pumps, which are greater in proportion than they would be on large pumps, which is true. The friction through the stuffing boxes and the bearings and other losses are proportionally higher in the small pump; but the biggest controlling factor is the fluid friction.

*Mr. Stewart:* A few years ago the University of Wisconsin was very fortunate in having appointed to its faculty a gentleman high in the ranks of engineers and well known to our society—Professor D. W. Mead—and through his influence the University of Wisconsin has been enabled to build up an hydraulic laboratory which has taken its place among the laboratories of the country in producing useful results. It was my good fortune to be associated with Professor Mead in his University work, and to have an opportunity of carrying out some of the plans which were outlined in this laboratory.

One of the first pieces of work started was an investigation of centrifugal pumps. In outlining the work, the attempt was made to reduce the problem to the most simple elements, to modify the design of the pump in only one particular element at a time, and to test the results of that change as regards efficiency and capacity. In starting the investigation, a study was made first of the effect of a change in the form of the impeller. Impellers were made having various numbers of vanes, varying from four to twenty-four vanes. In some of these impellers the vanes were radial, while in others the vanes were radial with the entrance to the impeller curved. The results of this portion of the work, dealing with the impellers (Part I of the investigation), were partially described by Professor Mead in a paper before the society in February, 1908.

At this time I shall take up some of the results in connection with Part II of the investigation, which shows the results of experiments with a 6 in. horizontal centrifugal pump, comparing the efficiency of circular and spiral cases, and the effect of air leakage.

#### DESCRIPTION OF SIX INCH, HORIZONTAL CENTRIFUGAL PUMP.

The following descriptive matter has been abstracted and rearranged from Bulletin No. 318 of the University of Wisconsin.

The pump shown in detail, Fig. 11, was designed as an experimental pump, and so arranged that various forms of impellers and pump cases could readily be used with it. The impellers were of the enclosed type,  $8\frac{1}{8}$  in. outside diameter, with 12 radial vanes. Throughout these experiments the impeller used remained the same, with its entrance modified by a suitable curve, to assure gradual change of direction of the water and entrance without shock. The outer portion of the metal of each vane had such a thickness that the area of cross-section of the waterways through the impeller remained practically constant from inlet to outlet. The impeller was attached to a brass casting, keyed to the pump shaft, as shown in Fig. 11. All surfaces of impeller and casting were smooth.

In Fig. 12 is shown the details of the *circular* and *spiral* cases

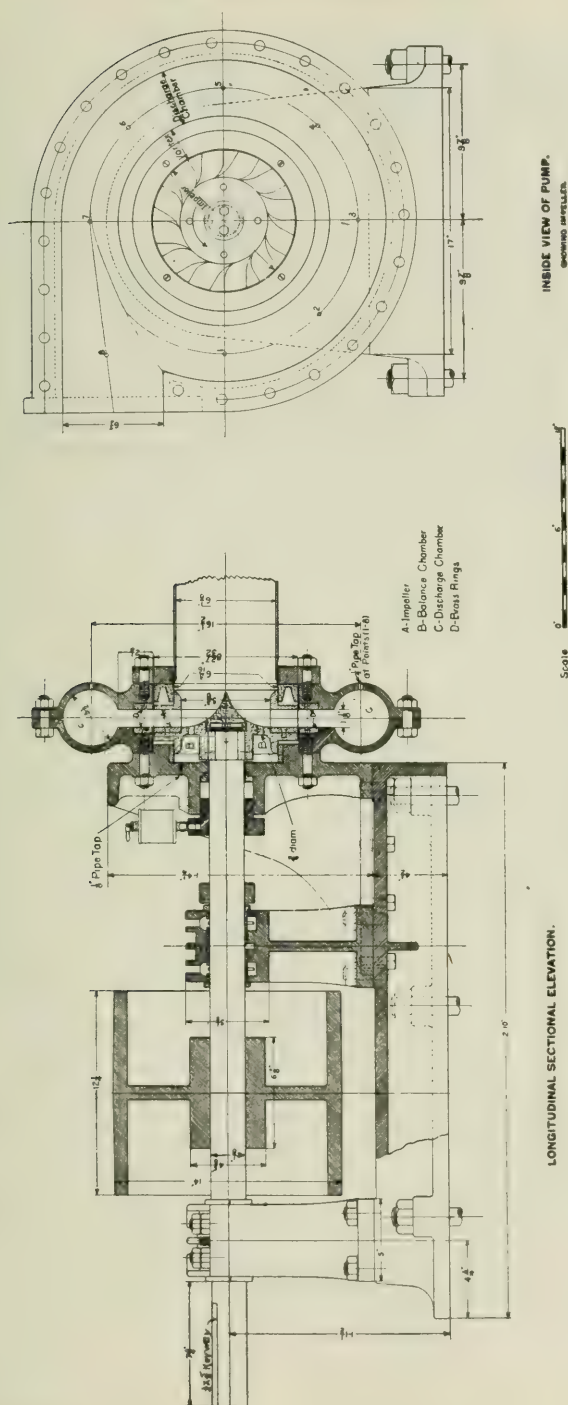


Fig. 11.—Experiments with a 6-inch Horizontal Centrifugal Pump.

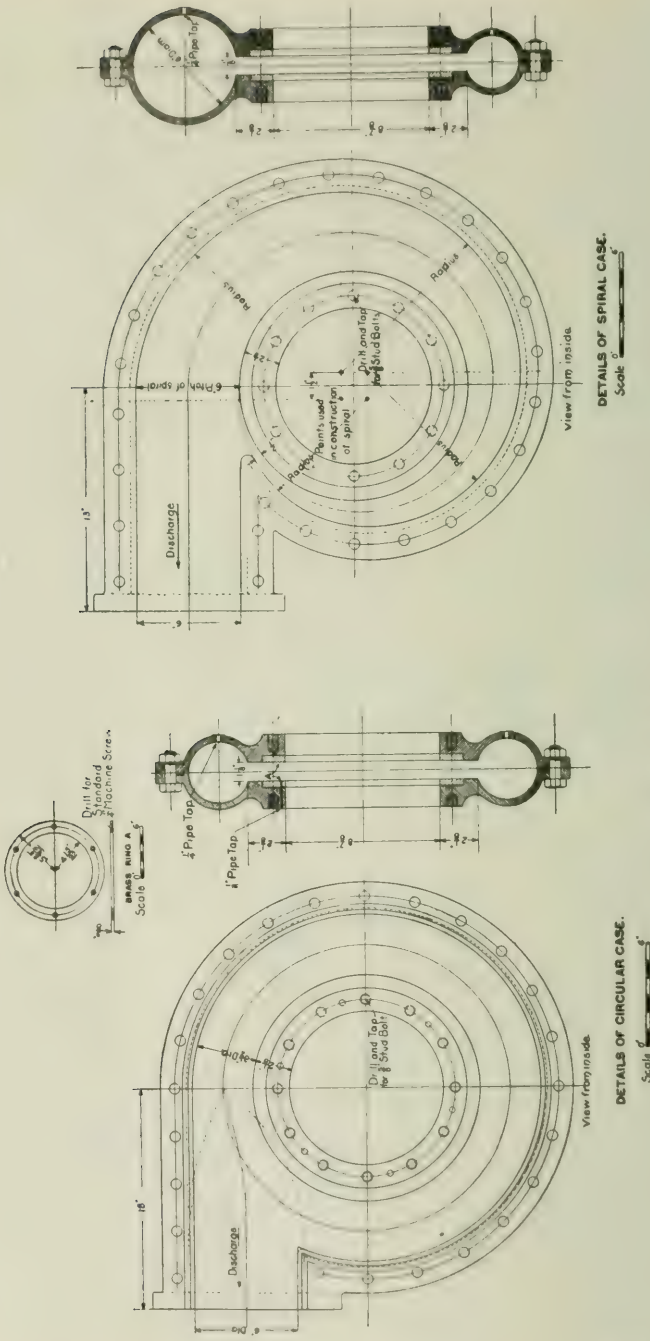


Fig. 12.—Experiments with a 6-inch Horizontal Centrifugal Pump  
Details of Circular Case and Spiral Case.

used in these experiments. In the *circular* case, the discharge chamber, which collects the water and leads it to the 6 in. discharge pipe, was circular in form and had a circular cross-section of  $3\frac{1}{2}$  in. diam. The connection to the 6 in. discharge pipe was made by gradually enlarging the cross-section, thus forming a diverging tube having a length of about 13 in.

In the *spiral* case, the discharge chamber was (approximately) spiral in form, the outer edge of the chamber being a four center curve, with a pitch of 6 in. in 360 deg. This chamber was circular in cross-section, except near the beginning, or throat, and with a gradually increasing diameter.

The beginning of the discharge or collecting chamber (the throat) was nearly closed in the spiral case, the dimensions being approximately  $1\frac{1}{8}$  by  $\frac{1}{2}$  in.; in the circular case the throat was open, circular in cross-section, and had a diameter of  $3\frac{1}{2}$  in.

The annular space extending from the periphery of the impeller to the entrance of the discharge or collecting chamber, is termed the vortex chamber. In both the circular and spiral cases experimented with, the form of the vortex chamber remained the same, being rectangular in cross-section,  $1\frac{1}{8}$  in. wide by  $2\frac{1}{8}$  in. long. It is proposed in future experiments to modify the form of the vortex chamber—for example, increase the outer width, make an expanding passage to the discharge chamber, and thus eliminate eddies.

A balance chamber, B, Fig. 11, on the rear side of the impeller, is connected to the suction side of the impeller by four holes, each  $\frac{3}{4}$  in. diam. The pump shaft was supported by brass lined bearings having ring oilers.

To measure the pressure and velocity at various points of the pump casing required a rather complicated system of gages. It was found that the pressures in various portions of the vortex chamber were less than atmospheric, and these required suction gages. Ordinary pressure and vacuum gages of the Bourdon type could not be depended on for values much closer than about one foot, and were discarded except for use as a check in certain cases of measurement of discharge and suction heads. Figure 13 is from a photograph showing the pump with connections to water gages and mercury manometer for measuring pressures, and in Fig. 14 is shown the general arrangement of the pressure and suction gages. At the points, Nos. 1-8 of the pump casing, are openings on the center line of the discharge chamber, which are connected by rubber tubing to the series of water gages Nos. 1-8 respectively. The piezometer for measuring discharge head, at 9, is connected to both mercury manometer No. 9 and to water gage No. 9. Provision was made for the admission of air, under a common pressure, to the tops of the water gages, so that each water column was depressed an equal amount, and by adjustment of the air pressure could be kept within the de-

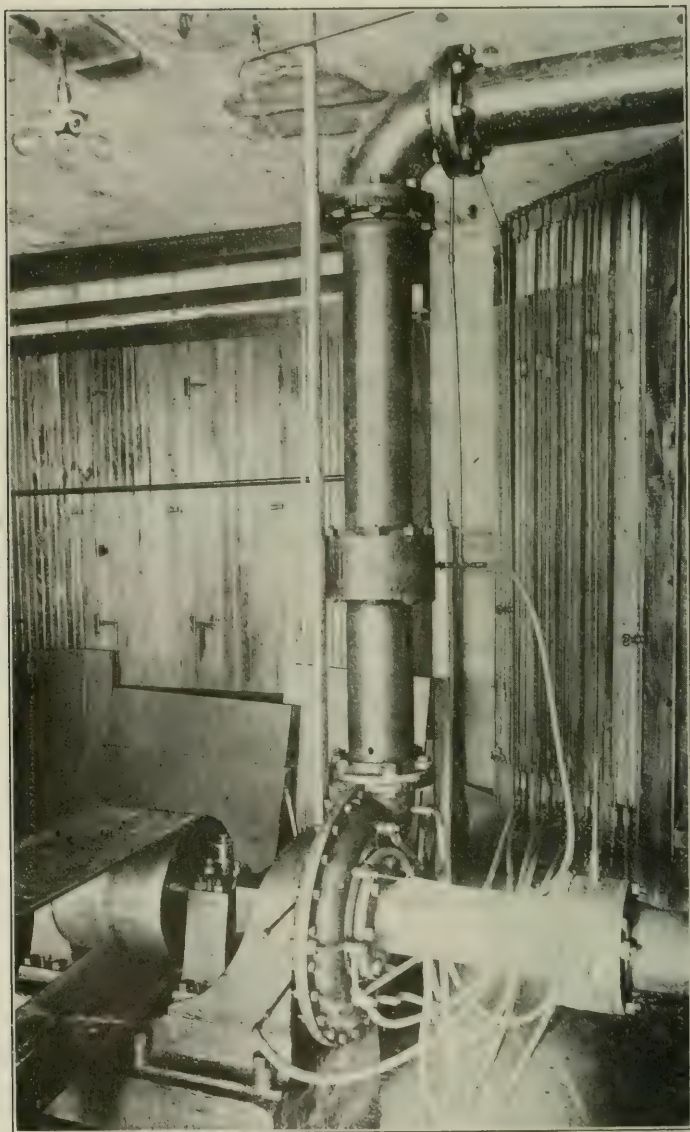


Fig. 13.—View Showing 6-inch Horizontal Centrifugal Pump and Arrangement of Gages.

sired range. The combination thus formed a differential water gage, the variations in pressure being determined from the readings of the gages, Nos. 1-8, the difference between the reduced points, Nos. 1-8, was determined by adding to each of the readings of the gages. Nos. 1-8 the difference between the reduced reading of mercury manometer No. 9 and water gage No. 9.

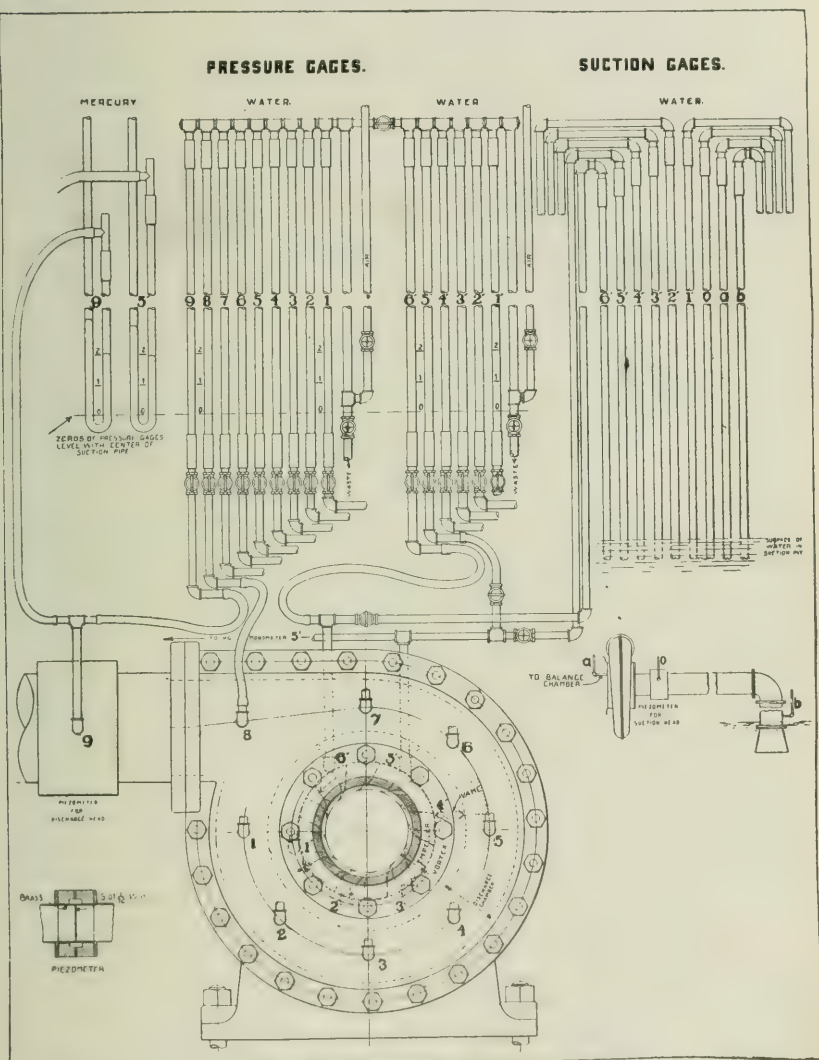


Fig. 14.—Experiments with a 6-inch Horizontal Centrifugal Pump.  
Sketch Showing Arrangement of Water and Mercury Gages.

Other openings into the vortex chamber were provided and shown at 1'-6', which could be connected to the suction water gages shown. When pumping against low heads and with large discharges, the pressure at these points of the vortex chamber was less than atmospheric. The height to which the water was lifted in the tubes, above the surface of the water in the suction pit, represented the pressure less than atmospheric, at the point of attachment of the tube to the vortex chamber.

Leakage of air into the pump was shown by attaching a short vertical glass tube to the upper side of the horizontal discharge pipe. This tube had a valve at the upper end, so that the air could be driven out when necessary. If there was an air leakage into the pump, a portion would slowly collect in this glass tube, the rate of collection serving somewhat as a measure of the rate of leakage. When first experimenting with the circular case, the air leaking into the pump was thought to be too small in quantity to materially affect the results, but further experiments showed the necessity of avoiding the leakage of air into the pump.

The effect of air leakage is shown by diagrams, Fig. 15. The amount of *air leakage, condition No. 1*, in the first experiments could not be determined volumetrically, as it was leakage through the stuffing box of the pump shaft. An approximate indirect determination, however, was made later by contriving a water seal to the stuffing box, and with the entrance to the pump under suction, and then admitting air to the suction side of the pump, and under known conditions so modified as to practically duplicate the condition No. 1. The amount of this *air leakage, condition No. 1*, was thus found to be a maximum of about 0.04 cu. ft. per sec. for the low heads pumped against. This leakage decreased as the head increased, becoming zero at the head of impending delivery.

The effect of air leakage on efficiency and capacity is shown in Fig. 15 by a comparison of the curves showing the efficiency for a certain speed (as 1,120 rev. per min.) under the two conditions, *entrance to the pump under pressure, and entrance to pump under suction, air leakage condition No. 1*.

The H. P. output consists of the product of the discharge and head, modified by a constant, hence the effect of air leakage into the pump is to reduce the discharge and thus the H. P. output is reduced in like proportion. The results of experiments, Fig. 15, show that leakage of air also decreases the H. P. input in about the same proportion for various heads from zero to about five feet less than the maximum head. Under these conditions the efficiency remains the same. For heads equal to or slightly less than the maximum head, the effect of air leakage is to reduce the discharge (or horsepower output) to a greater extent than the H. P. input, resulting in a lessened efficiency.

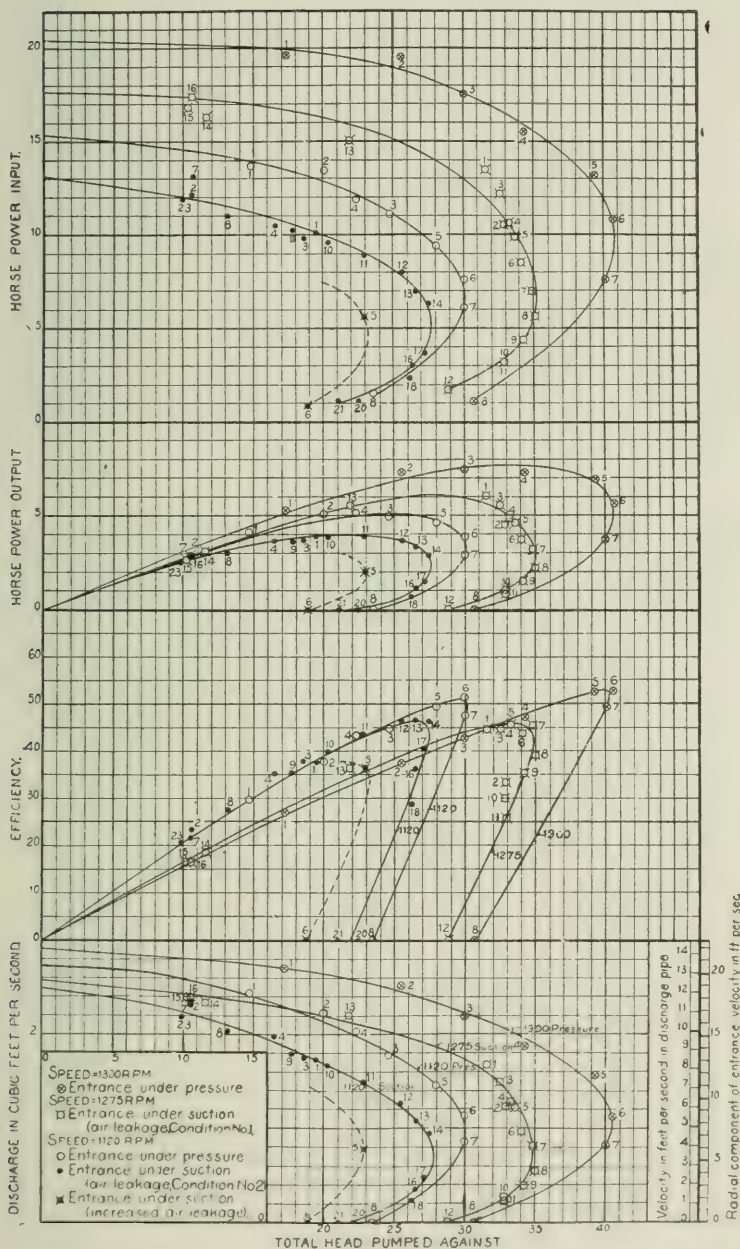


Fig. 15.—Experiments with a 6-inch Horizontal Centrifugal Pump. Circular Case; Comparison of Results, Entrance to pump under Pressure and Entrance to Pump under Suction with Air Leakage, Condition No. 1.

For the speed of 1,120 rev. per min. the reduction in maximum efficiency amounted to about 5%.

The conclusions as to the effect of leakage of air at the economical condition of working, speed 1,120 rev. per min., and head about 29 ft., are that with an air leakage not to exceed about 0.01 cu. ft. per sec., equal to about 1% of the volume of water discharged, there was a decrease in head of about 10%, a decrease in discharge of about 15%, and a decrease in efficiency of about 5%. If the head was maintained constant the effect on discharge would be very much increased, and would be equal to from 20 to 25%.

An air leakage to the amount of 0.01 cu. ft. per sec. would easily pass unobserved in the ordinary working of a centrifugal pump, while the amount of 0.04 cu. ft. per sec. would probably be noticed by a careful observer, by the drawing in of oil through the stuffing box around the pump shaft. A glass tube, placed on the discharge pipe as described, furnishes a practical means for testing for air leakage.

#### RESULTS WITH PUMP HAVING SPIRAL CASE.

*General Forms of Curves Showing Characteristics of the Pump with Spiral Case.* In Fig. 16 is shown the results of experiments with the spiral case, with entrance to pump under pressure, and may be taken as typical of the results with the 6 in. pump. The discharge was greatest for the low heads pumped against, and gradually decreased in amount as the head increased, until the maximum head was reached. From this point both the discharge and head pumped against decreased, until the head of impending delivery was reached, when the discharge was zero. It will be seen that the pump delivered water against heads higher than the head of impending delivery, and that a portion of the kinetic energy of the water, in the form of velocity head, was recovered in the form of pressure head, as the water passed through the casing of the pump.

From the experimental results at the three speeds, 1,120, 1,300 and 1,500 rev. per min., Fig. 16, a set of curves, termed a *characteristic curve*, Fig. 17, has been drawn as one diagram, on which are shown, by means of rectangular co-ordinates and contour lines, all the characteristics of the pump, at all speeds, within the range of the observations.

In this diagram the abscissae represent speed of the pump and the ordinates represent discharge. The numerical values of head pumped against, horsepower input, horse-power output, and efficiency, are obtained by interpolation between the various contour lines by which they are respectively represented. The diagram was constructed by noting on each of the vertical lines representing the speeds of 1,120, 1,300 and 1,500 rev. per min. numerical values of the experimental results as shown by the

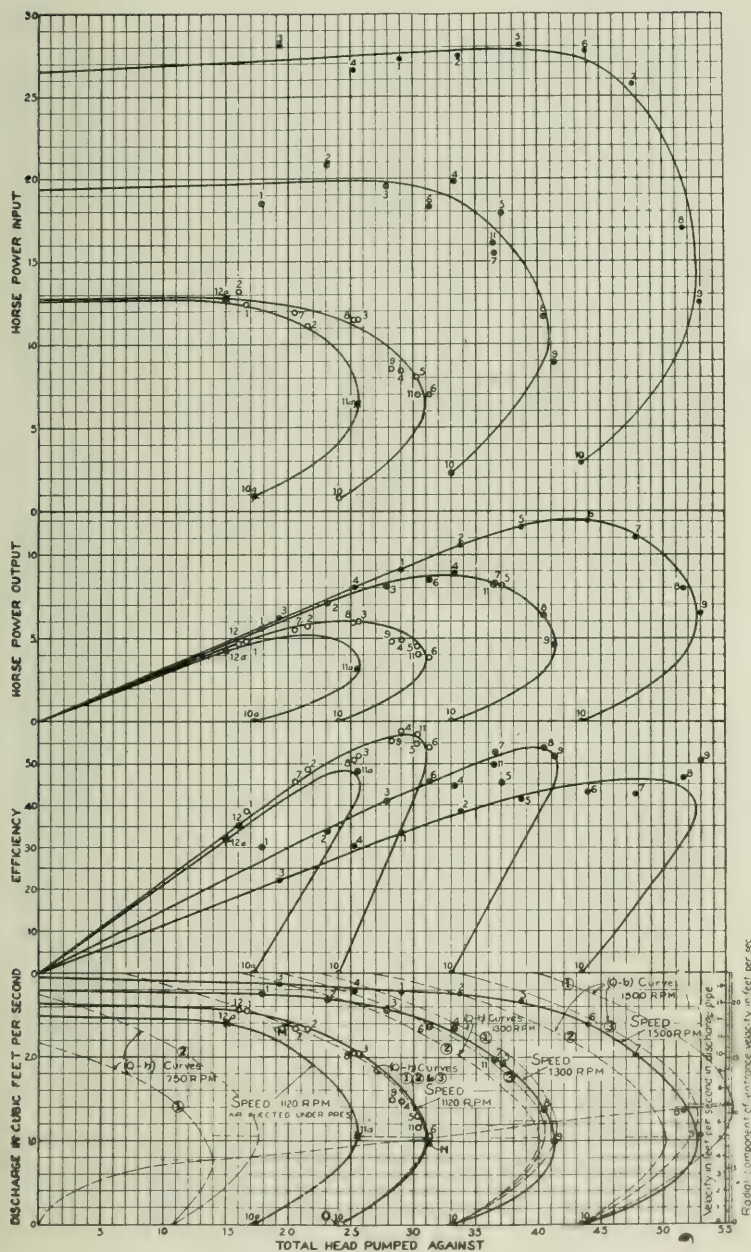


Fig. 16.—Experiments with a 6-inch Horizontal Centrifugal Pump. Spiral Case; Entrance to Pump under Pressure.

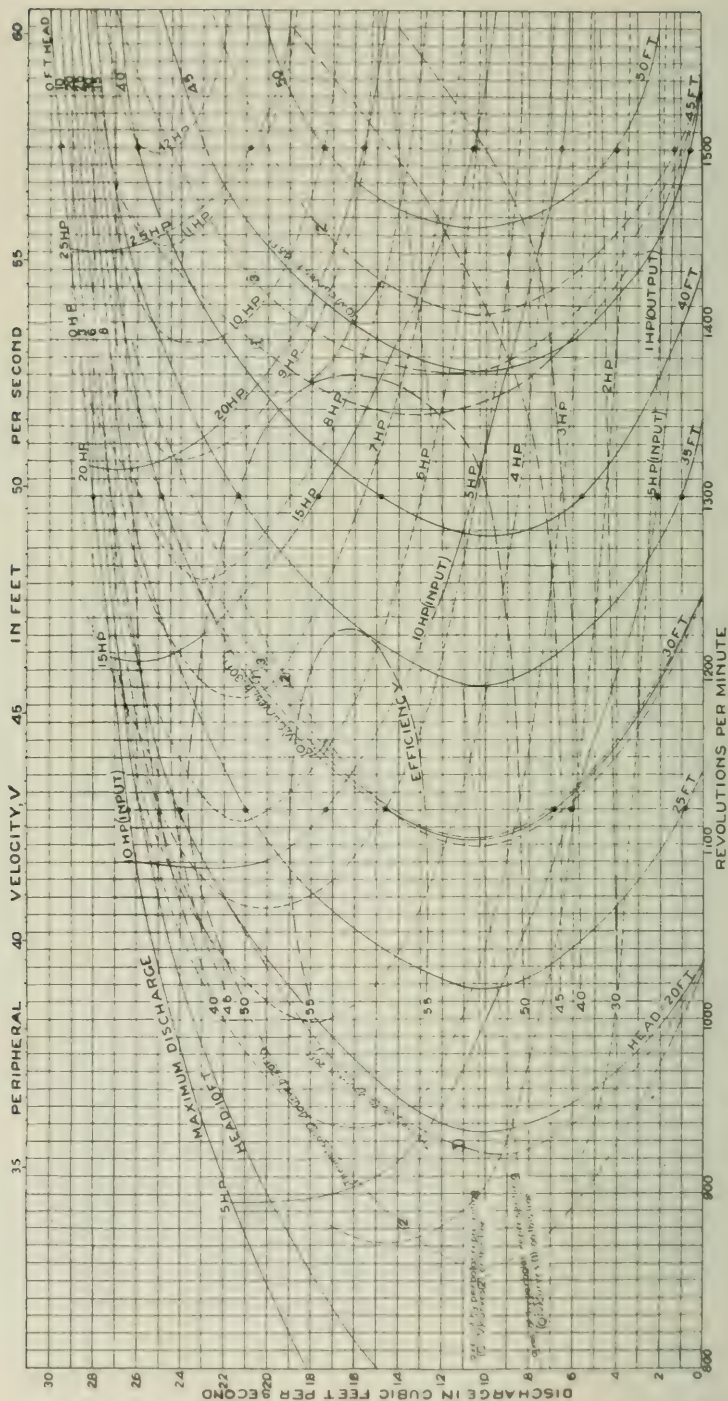


Fig. 17.—Characteristic Curve, Showing Results of Experiments with Pump Having Spiral Case.

respective average curves on Fig. 16, and finally adjusting contour lines to the plotted points. For example, on Fig. 16, speed 1,120 rev. per min., the vertical line representing 25 ft. head pumped against, crosses the curve representing discharge at two points, and the numerical values of the discharge served to locate two points, on the characteristic diagram, through which to draw the curve representing 25 ft. head pumped against. Values of the horsepower output, horse-power input and efficiency, corresponding to these discharges and 25 ft. head pumped against, were also noted on the diagram. The process was repeated for at least each multiple of five feet of head pumped against, and covered the entire range of head from zero to the maximum. The discharge corresponding to zero head pumped against gave one point for the curve of maximum discharge on the characteristic diagram. The experimental data, as shown by the curves for speeds of 1,300 and 1,500 rev. per min., were transferred to the characteristic diagram in a similar manner. Contour lines were finally adjusted to fit the various values noted on the diagram.

Referring to the curve representing 35 ft. head, and considering that the pump is to overcome a head of 35 ft. between water levels, with the valve in the discharge pipe wide open, the pump will not commence to deliver water until a speed of 1,340 rev. per min. has been reached. There will then be a rapid increase of discharge, until a balance is reached, when the discharge is 2.3 cu. ft. per sec. The variation in discharge due to any variation in speed will then be shown by the curve representing 35 ft. head. The diagram thus shows, in a condensed form, all the characteristics of the pump. For example, assuming a fixed head pumped against, and a required increase in discharge, the diagram shows the necessary increase in speed and the resulting change in efficiency and power required. For the above case with a head of 35 ft. if the speed of the pump were reduced below the value 1,190 rev. per min. the delivery of water would cease. The values of the discharge represented by the under part of the curve for speeds greater than 1,190 rev. per min. could be only obtained by partially closing the valve in the discharge pipe. There was therefore a certain minimum value of the discharge which could be obtained with the valve wide open, and this value, one cubic foot per second for the present case, is seen to have been practically independent of the head and speed.

#### COMPARISON OF RESULTS WITH THE SPIRAL AND CIRCULAR CASES.

In order to show the comparison of the results of the experiments with the two casings, Fig. 18 has been arranged. Curves A and B represent respectively the results with the spiral and circular cases at the speed of 1,120 rev. per min., while curves C and D represent corresponding results at 1,300 rev. per min.

Referring to the *efficiency-head* curves; for a speed of 1,120 rev. per min., the efficiency curve for the spiral case lies entirely above that for the circular case, the maximum efficiency with the *spiral* case being about 57%, or 6% greater than the maximum efficiency with the *circular* case. For the speed of 1,300 rev. per min., the difference of the maximum efficiencies is apparently not so great, being about 2% in favor of the spiral case.

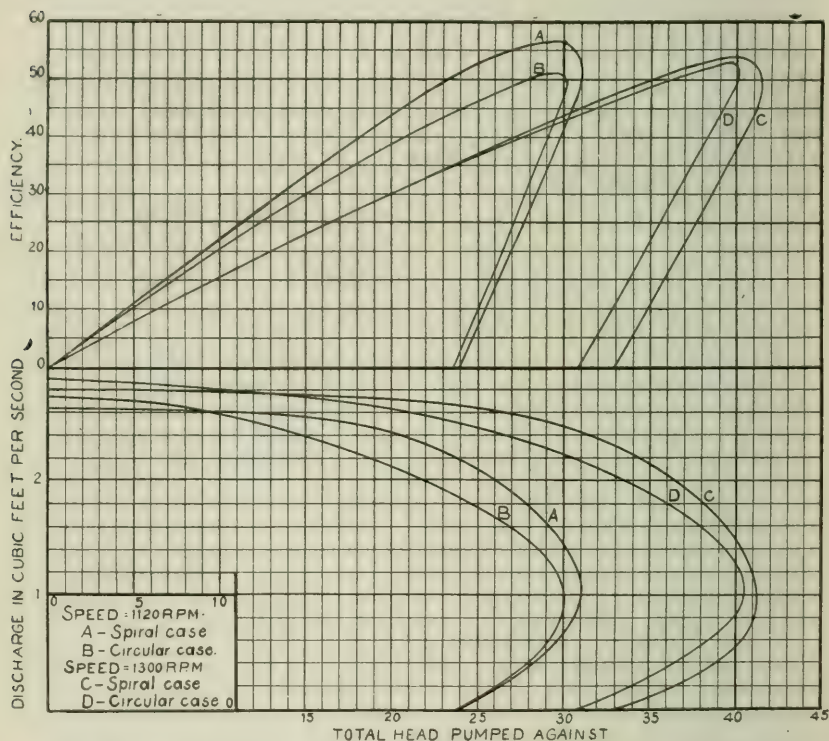


Fig. 18.—Experiments with a 6-inch Horizontal Centrifugal Pump. Comparison of Results of Experiments with Circular Case and Spiral Case.

Referring to the *discharge-head* curves; for heads up to about 10 ft., the discharge is seen to be slightly greater with the circular case, while for heads between 10 ft. and the maximum head which the pump will hold up, the discharge for a given head is uniformly about 20% greater with the spiral case. With the speed of the pump at 1,120 rev. per min., the spiral

case, therefore, when working under the most economical condition (capacity about 1.4 cu. ft. per sec., and head about 30 ft.), would furnish about 20% more water than the circular casing, and would have about 5% greater efficiency. The percentage increase in power required for the 20% increase in discharge would amount to about 12%. For the speed, 1,300 rev per min., the comparison is not quite so favorable to the spiral casing, 17% increase in power being required for the 20% increase in discharge.

If the speed of the pump with the spiral case is *reduced* from 1,120 to about 1,100 rev. per min., the curve showing relation of discharge to head pumped against would practically coincide with the similar curve for the pump with the circular case, at the speed of 1,120 rev. per min., and at the condition of economical working, the discharge being about 1.4 cu. ft. per sec., and head pumped against about 28.5 ft. The H. P. output in raising the water through the given head would then be the same for the two pump cases, and the H. P. input required would be inversely as the efficiencies of the two cases. Assuming efficiencies of 57% and 52%, the pump with the circular case would require about 10% more power to pump the same quantity of water against a given head, and the speed would have to be about 20 rev. per min. greater. At the speed of 1,300 rev. per min., the comparison became slightly more favorable to the circular case, the results showing that about 4% more power was required with the circular case for the same amount of water delivered.

#### MEASUREMENT OF PRESSURES AND VELOCITIES IN PUMP CASING.

The general description of the apparatus, as arranged for the measurement of the pressures at various points of the discharge chamber and vortex, together with the method of using the same, has been given under the description of mercury manometers and water gages. The pressures at points Nos. 1-8 and 1'-6', Fig. 19, are platted on a development of a cylindrical surface passing through the points Nos. 1-7, the location of the points Nos. 1'-6' being determined by projection radially on the cylindrical surface; thus values of 1' and 1 are platted on the same initial vertical line, and values at 4' and 5 also appear on a common vertical line. The values platted represent the pressures in feet of water at the various points, the zero of each water gage being at the same elevation as the center of the suction pipe.

In order to further analyze the gain of head resulting from the reduction of velocity when the water entered the discharge chamber, and also to determine the loss of head resulting from the gradual enlargement of the cross-section, where the discharge chamber joins the discharge pipe, measurements of the velocities

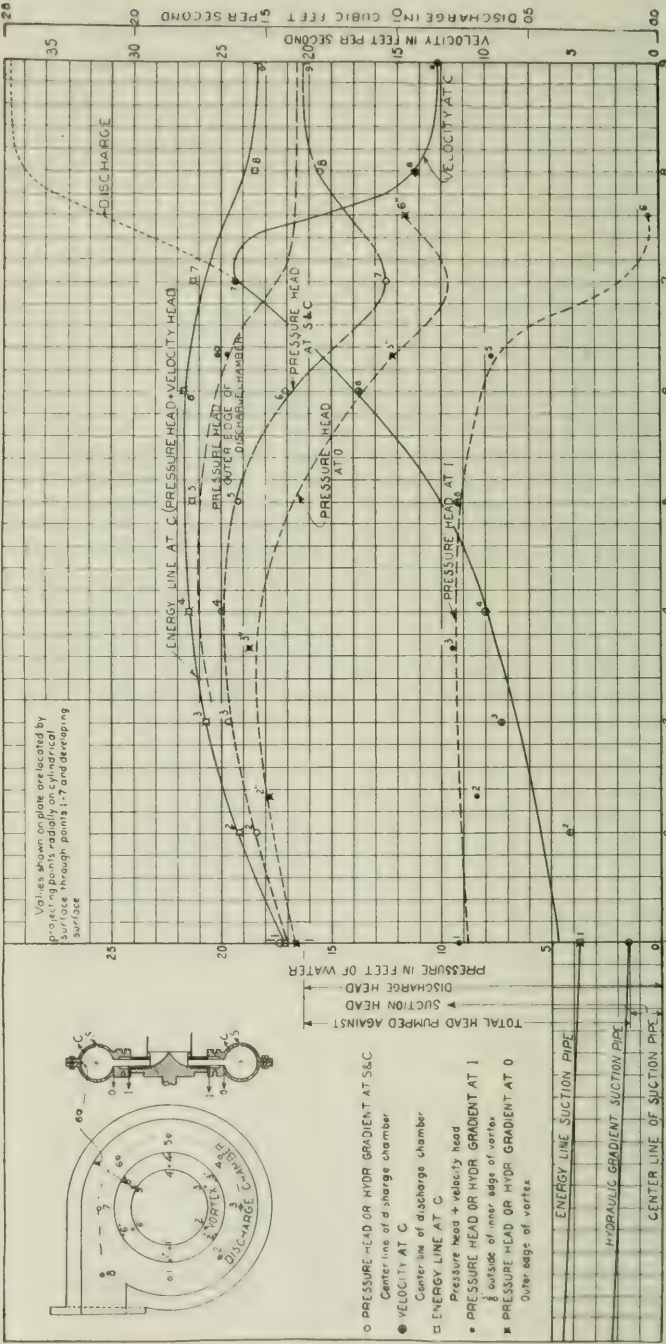


Fig. 19.—Diagram of Pressures and Velocities in Circular Pump Case.  
Speed of Pump 1.120 R. P. M., Discharge 2.44 Cubic Feet per Second.  
Efficiency about 30 per cent.

were made at points Nos. 1-8 on the center line of the discharge chamber. The velocities were measured by means of a simple form of pitot tube, shown in the engraving, Fig. 20, A, and details, Fig. 21. The pitot tube was made from a copper tube

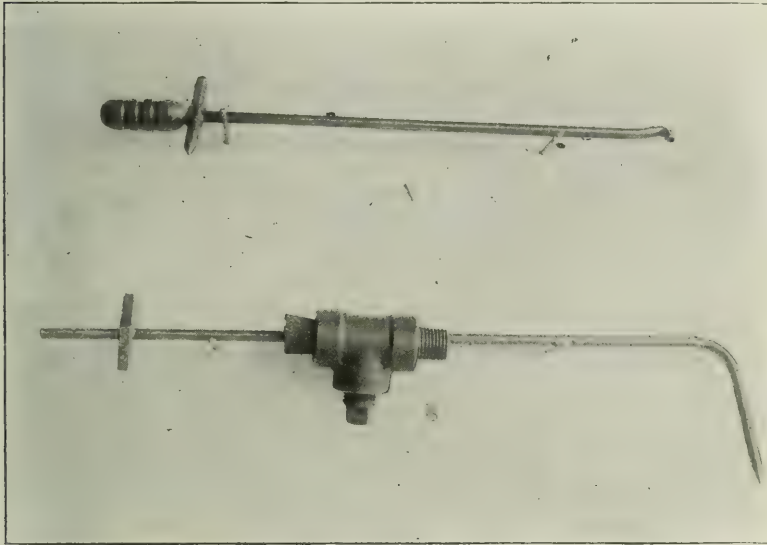


Fig. 20.—View Showing Forms of Pitot Tube and Pressure Tube.

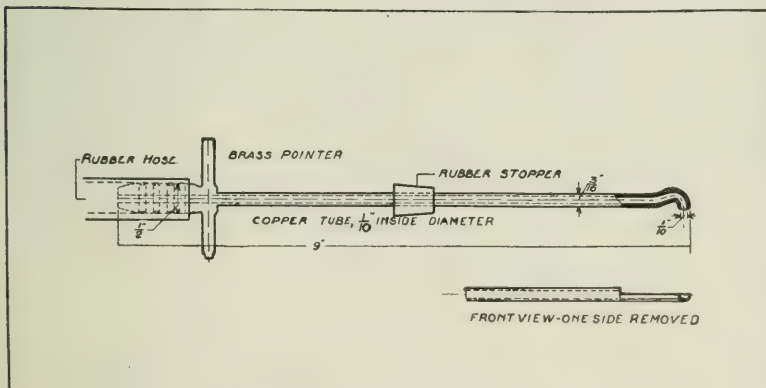


Fig. 21.—Details of Pitot Tube.

about 0.1 in. inside diameter, the opening to the tube being beveled on the outside so as to make a moderately sharp edge. The tube could be inserted in the discharge chamber, at points

Nos. 1-8, through one-quarter inch iron tees, attached to the pump casing at these points. The pressure head was obtained by the readings of the water gages connected to the discharge chamber at these points. To determine if the pressure head was constant throughout the diametrical section, a form of pressure tube shown in Fig. 20 B, was inserted in the discharge chamber at S, with the sharp end pointing up stream, and the readings of the pressures throughout the width of the discharge chamber, compared with the readings of pressures obtained at the surface of the chamber at S by means of the water gages. The comparisons showed that the pressures were constant throughout the diametrical section, and that readings of pressures at S by means of the water gages, indicated correct values. The length of the portion of the pressure tube pointing up stream was  $2\frac{1}{2}$  in. and the pressure was transmitted through four holes, each 1-32 in. diameter, located as shown.

## REFERENCES.

Bulletin of the University of Wisconsin, No. 173, Engineering Series, Vol. 3, No. 6, pp. 447-588. Investigation of Centrifugal Pumps. Part I. Clinton B. Stewart, C. E., Madison, Wis. October, 1907.

Bulletin No. 318, Engineering Series, Vol. 5, No. 3, pp. 189-318. Investigation of Centrifugal Pumps. Part II. Clinton B. Stewart.

In the second of these bulletins the method of calibrating the pitot tube is described in detail. There is also a description of a device for investigating the flow of the water in the suction pipe near the pump, wherein it was shown that there was a rotary motion in the column of water, which was probably induced by the action of the vanes of the impeller, and which might have an influence on the efficiency of the pump. There is also an investigation for an approximate law for discharge of a centrifugal pump, somewhat mathematical in its treatment, which forms an interesting study.

## IN MEMORIAM.

WILLIAM MEIER, M. W. S. E.

Died February<sup>14</sup>, 1910.

William Meier, the son of Rev. Jacob L. and Mary Meier, was born in Muscatine, Iowa, April 10, 1878, and during that same year his parents moved to Chicago, where they have since resided.

Mr. Meier received his education in the schools of Chicago and at the University of Illinois, graduating from the latter in 1901 in Civil Engineering, with the degree of Bachelor of Science.

He began the practice of his profession immediately after graduating from college, and his experience from 1901 to 1905 was as follows: Transitman, with Elgin, Joliet & Eastern Ry., Joliet, Illinois. Structural steel detailing for the American Bridge Co., Chicago. Engineer on Construction, Illinois Tunnels Construction Co., Chicago. Engineer on Construction, Spring Valley bridges for the Illinois Valley Traction Co., La Salle, Ill. Detailing and designing steel for Thatcher A. Parker, Bridge Shops, Terre Haute, Ind. Designing structural steel for Wm. M. Hughes, and later for the John S. Metcalf Co., Chicago.

In January, 1905, he accepted a position with the Scherzer Rolling Lift Bridge Co., Chicago, his work being in the nature of bridge designing, strain sheets, estimating, checking, inspection, and in charge of construction. Later, he acted as representative of that firm in New York City. At the time of his death he was in the Bridge Department of the Chicago & North Western Ry. Co.

On the 14th of February, 1910, in diving from a spring board in the Y. M. C. A. Natatorium, he was stunned by striking his head against the side or bottom of the tank; when taken out of the water every effort was made to restore consciousness, but without success.

Mr. Meier was an Active member of the Western Society of Engineers, and also an Associate Member of the American Society of Civil Engineers. He was of a progressive nature, taking great interest in all that pertained to his profession.

E. J. FUECK,

WM. A. THEODORSON,

Committee.

# PROCEEDINGS OF THE SOCIETY.

## MINUTES OF THE MEETINGS.

*Regular Meeting, March 2, 1910.*

A regular meeting of the Society (No. 692) was held in the Society Rooms, Wednesday evening, March 2d.

The meeting was called to order about 8:20 p. m., with Mr. O. P. Chamberlain in the chair, and about 45 members and guests present.

The minutes of the meetings of February 2d and 16th were read and approved.

The Secretary reported from the Board of Direction that the following had applied for membership in the Society:

	GRADE.
Lewis E. Myers, Chicago.....	Active
Ralph O. Beck, Sioux City, Iowa.....	Junior
J. W. Mabbs, Chicago.....	Active
Robert Hamilton, Milwaukee.....	Active
Andrew S. Armstrong, Chicago.....	Active
Edward M. Lara, Chicago.....	Junior
F. W. Kassebaum, Jr., Chicago.....	Active
Thomas Crawford, Clinton, Iowa.....	Active

Also that the following had been elected into membership:

	GRADE.
1909.	
160, A. O. Anderson, Lake City, Iowa.....	Active
175, Emory F. Hartzell, Chicago.....	Active
186, Christian P. Berg, Chicago.....	Active
187, Frank G. Walter, Jr., New Orleans, La.....	Junior
188, Earl W. Evans, Chicago.....	Junior
190, Frank T. Fowler, Chicago.....	Associate
191, Eugene F. Hunter, Chicago.....	Junior
192, Lindon Bates, Jr., New York.....	Active
197, Grant D. Bradshaw, Chicago.....	Junior
199, McClellan Davis, Chicago.....	Junior
1910.	
7, Harold H. Simmons, Chicago.....	Junior
14, B. E. Sunny, Chicago.....	Active
15, Philip G. Connell, Chicago.....	Junior
16, Jesse L. Haugh, Clyman, Wis.....	Junior
17, Joseph L. Hiller, Philadelphia.....	Active
18, Charles B. Nolte, Chicago.....	Junior
20, Louis C. Fritch, Chicago.....	Active
22, Harold W. Snell, Chicago.....	Junior
25, J. W. Mabbs, Chicago.....	Active
26, Robert Hamilton, Milwaukee, Wis.....	Active

That a petition for the formation of a Section devoted to matters of municipal interest had been presented to the Board of Direction, and was by them referred to the Society.

That President Alvord had received a letter from Mr. Julian Griggs, of Columbus, Ohio, relative to this Society taking action (or otherwise) on endorsing and favoring H. R. bill 27372 now before Congress, and that the Board of Direction had referred this matter to the Society. This bill now before Congress is for the betterment of the service of the Corps of Engineers, under whose care is the work of improvements of the rivers and harbors of the country. The bill provides for an increase in the number of officers of the Corps of Engineers, and how this increase shall be made, and for the appointment of civilian engineers to the Corps of Engineers after competitive examination.

After some discussion the matter was referred to a committee,

consisting of Messrs. Strehlow, Dart, and Bement, to consider the idea of the Society taking some action on this bill, and to report to the Society at the next meeting, March 16th.

There being no other business before the Society, Mr. E. McCullough, on behalf of his friend, the author, read the paper by Mr. J. W. Phillips, of California, on "Hydraulic Mining of Auriferous Gravels."

Discussion followed from Messrs. Wm. B. Storey, Jr.; I. F. Stern, J. G. Elliott, E. McCullough, J. H. Warder, O. E. Strehlow, and A. Bement. The meeting adjourned about 10:45 p. m.

*Extra Meeting, March 9, 1910.*

An extra meeting of the Society (No. 693), being the fifth meeting of the Bridge and Structural Section, was held Wednesday evening, March 9, 1910.

The meeting was called to order about 8:20 p. m. with Mr. T. L. Condron, Chairman of the Section, presiding and about 100 members and guests present. The minutes of the preceding meeting of the Section were read and approved.

Mr. F. E. Davidson, M. W. S. E., was introduced, who read his paper on "Some Unusual Problems in Building Design." This was illustrated by a number of stereopticon views. Discussion followed from Messrs. T. L. Condron, Andrews Allen, Gordon F. Dodge, E. N. Layfield, R. M. Gerety, Wm. G. Langenheim, S. L. Pierce, W. R. Patterson, and W. R. Hoyt.

The meeting adjourned about 10:30 p. m.

*Extra Meeting, March 16, 1910.*

An extra meeting of the Society (No. 694) was held Wednesday evening, March 16, 1910.

The meeting was called to order at 8:20 p. m. with Vice-President Bement in the chair and about 60 members and guests present.

The Secretary read a short portion of the minutes of the meeting of March 2d, relating to the appointment of a committee—Messrs. Strehlow, Dart, and Bement—and also read their report. This related to the matter of a bill before Congress for increasing the efficiency of the Engineer Corps of the Army and providing for the admission of civilian engineers to rank in this service. The committee report was presented with a set of resolutions expressing approval of the measure. No action was taken, however, but a motion was made to refer the matter back to the committee, the committee to be enlarged by the addition, by the President, of some other members who were somewhat familiar with this question in the past. The motion carried.

The Chairman then introduced Prof. C. E. A. Winslow, of the Massachusetts Institute of Technology, who addressed the meeting on "The Jersey City Water Supply Case, a Historic Sanitary Lawsuit." This very interesting and instructive lecture was illustrated by means of a map and a diagram.

Discussion followed from Prof. A. N. Talbot, B. J. Ashley, C. D. Hill, Dr. Tonney, Langdon Pearse, H. B. Herr, and C. B. Burdick, with a closure from Prof. Winslow.

On motion of Mr. Burdick, a vote of thanks was returned to Prof. Winslow for his very interesting and instructive address.

*Extra Meeting, March 23, 1910.*

An extra meeting of the Society (No. 695), being the 49th meeting of the Electrical Section, W. S. E., held jointly with the Chicago Section of the American Institute of Electrical Engineers, was held Wednesday evening, March 23, 1910.

The meeting was called to order at 8:20 p. m., with Mr. G. H. Lukes,

April, 1910

Chairman, presiding and about 75 members and guests present. The minutes of the preceding meeting of February 23d were read and approved.

Mr. H. B. Gear, M. W. S. E., was then introduced, who presented his paper on "The Diversity Factor in the Distribution of Electric Light and Power." This was illustrated by a number of diagrams by the aid of the stereopticon and also two tables of figures on the blackboard.

Discussion followed from Messrs. Wm. B. Jackson, W. L. Abbott, H. Almert, S. M. Bushnell, P. B. Woodworth, A. Bement, F. F. Fowle, G. H. Lukes, and a closure from Mr. Gear.

Professor Woodworth moved a vote of thanks to the speaker for his admirable and very valuable paper, which was carried unanimously.

The meeting adjourned about 10 p. m.

#### *Regular Meeting, April 6, 1910.*

A regular meeting of the Society (No. 696) was held in the Society rooms, Wednesday evening, April 6, 1910.

The meeting was called to order at 8:20 p. m., with Vice-President O. P. Chamberlain presiding, and about 90 members and guests in attendance.

The minutes of the meetings of March 2d and 16th were read and approved. In the matter of a committee (Messrs. Strehlow, Dart, and Bement), appointed to consider and report on a bill before Congress for increasing the efficiency of the Corps of Engineers and adding civilian engineers to the Corps, the Secretary stated that President Alvord had added to that committee Messrs. W. L. Abbott, Onward Bates, J. M. Ewen, H. B. Herr, and J. S. Metcalf, and that the committee had held one meeting and reported progress.

The Secretary reported from the Board of Direction that the following had made application for membership:

W. H. Warner, Chicago.....	Junior
Hugh L. Lucas, Chicago.....	Active
A. F. Robinson, Chicago.....	Active
Millard Gilmore, Chicago.....	Junior
R. H. Slocum, Fargo, N. D.....	Active

The Chairman then introduced Mr. Charles K. Mohler, M. W. S. E., who read his paper on "Earth Pressures" with stereopticon illustrations. Discussion followed from Messrs. E. McCullough, W. M. Wilson, W. H. Finley, W. C. Armstrong, E. N. Layfield, I. F. Stern, O. P. Chamberlain, and a closure by Mr. Mohler.

The meeting adjourned at 11 p. m.

#### *Extra Meeting, April 13, 1910.*

An extra meeting of the Society (697), being the sixth meeting of the Bridge and Structural Section, was held Wednesday evening, April 13, 1910.

The meeting was called to order at 8:20 p. m., with Mr. T. L. Condon, Chairman, presiding and about 70 members and guests present. The minutes of the preceding meeting of the section were read and approved.

Mr. C. H. Cartlidge, M. W. S. E., was introduced, who read his paper on "Reinforced Concrete Trestles," which had been printed in advance. There were a number of lantern slide illustrations of the subject. Discussion followed from Messrs. O. E. Strehlow, I. F. Stern, E. N. Layfield, M. K. Trumbull, S. T. Smetters, A. C. Warren, H. S. Crocker, Wm. Dean, and F. E. Davidson.

The meeting adjourned at 10 p. m.

*Extra Meeting, April 20, 1910.*

An extra meeting of the Society (No. 698) was held Wednesday evening, April 20th.

The meeting was called to order at 8:20 p. m., with Vice-President Bement in the chair and fully 100 members and guests present, nearly one-half of whom were ladies.

The Secretary reported an invitation from the Chicago Architects' Business Association to the members of the Western Society of Engineers to attend a lecture by Mr. Henry A. Gardner, of Philadelphia, on "Protective Coatings for Various Structural Materials," to be given at the Art Institute, Tuesday, April 26th, at 8 p. m.

The Chairman then introduced Prof. J. Paul Goode, of the University of Chicago, who gave a delightful and instructive lecture on European Harbors. The address was illustrated by a large number of stereopticon views of the principal harbors of Europe, including the British Isles.

The meeting passed a vote of thanks to Prof. Goode and adjourned about 10 p. m.

*Extra Meeting, April 27, 1910.*

An extra meeting of the Society (No. 699), being the 50th meeting of the Electrical Section, held jointly with the Chicago Section of the American Institute of Electrical Engineers, was held Wednesday evening, April 27, 1910.

The meeting was called to order at 8:20 p. m., with Mr. J. G. Wray, M. W. S. E., chairman of the Chicago Section A. I. E. E., in the chair, and about 100 members and guests in attendance.

The minutes of the meeting of March 23d were read and approved.

The chairman then introduced Mr. Wm. B. Jackson, M. W. S. E., who read his paper on "Depreciation and Reserve Funds of Electrical Properties." A full and interesting discussion followed from the chairman and Messrs. C. M. Duffy, of Milwaukee, George Weston, C. A. Ubelacker, of Ford, Bacon & Davis, New York; E. J. Fowler, H. Almert, W. L. Abbott, John S. Allen, George H. Lukes, George W. Craven, J. R. Cravath, T. Milton, E. N. Lake, F. Shumacher, A. W. Stager, with a closure by Mr. Jackson.

Mr. F. H. Reed, of Telephony, sent in a written discussion, which was read by Mr. S. R. Edwards.

Mr. Ralph W. Pope, Secretary of the American Institute of Electrical Engineers, New York, was present, and on being introduced offered some few remarks about the Institute and the work being done by the parent society and the local sections, and stated that he was now on a tour visiting the latter.

The meeting adjourned about 10:50 p. m.

J. H. WARDER, Secretary.

## BOOK REVIEWS.

**MUNICIPAL GOVERNMENT.** By Frank J. Goodnow, LL. D. Eaton Professor of Administrative Law and Municipal Science in Columbia University. The Century Co., New York, 1909. Cloth, 5½ by 8½ inc.; pp. 401, including index.

We have recently had occasion to notice Professor Rowe's book on city government. The present volume is perhaps a less interesting book to the general reader, but on the other hand, it is more comprehensive, more thorough, and more orderly in its arrangement. The purpose of the work is stated to be to provide a text-book for college and high-school students, of interest to the general reader also, which shall cover the entire field of Municipal Government. This purpose, difficult as it is, has been admirably accomplished, although necessarily with some sacrifices to brevity and compendiousness.

The opening chapters on "Urban Growth," "Trade and Industry," and "The Character of City Population," trace the general causes to nothing above the aggregations we call cities and broad characteristics of such aggregations. Then follows a more connected history of city development under the Roman Empire during the Middle Age and subsequently up to modern times—a story extremely interesting in many of its phases to one with a taste for historical generalizations but which, because of the diversity of the conditions prevailing at different epochs of history, offers very little of value toward the solution of modern municipal problems. The modern history of city government begins at the nineteenth century, hardly before that, with the realization that the city government is, or should be, the organ for the satisfaction of local needs, and the larger portion of Prof. Goodnow's book is devoted to this modern epoch. The discussion is methodical, the author taking up in separate chapters the City Council. The City Executive, Police Administration, Charities Administration, Education Administration, Local Improvements, and Financial Administration, and gives a thorough, though necessarily brief consideration of these topics. The final chapter is devoted to Conclusions, and not the least interesting is the author's conviction that the government of cities tends inevitably to become oligarchic or despotic—witness Venice in the past and our own American boss government of the present time. The author's remedy seems to be division of authority, state control, diminution of the number of elective officers, and election of officers by districts. This is a program hardly appealing to more advanced thinkers on civic matters. However, there is something to be said in its favor and the author says it well. The book, on the whole, is of very considerable value. It presents a vast amount of information well digested, excellently arranged, and in an interesting form.

P. H. T.

**DESIGNING AND DETAILING OF SIMPLE STEEL STRUCTURES.** By Clyde T. Morris, Assoc. M. Am. Soc. C. E., Professor of Structural Engineering, Ohio State University. Ohio State University Civil Engineering Publications, Columbus, Ohio. Cloth, 6 by 9 ins.; pp. 201; illustrated. Price, \$3.00.

With the exception of occasional chapters in exhaustive treatises on bridge and structural engineering, there has been but little published dealing specifically with good practice and methods in the designing and detailing of steel structures. The subject of stresses appears to be sufficiently covered. There is no lack of books on this subject, and it is a favorite study in all technical schools. But the art of producing "details which are in accord with the stresses they have to transmit" has been practically overlooked, or left to be picked up by the engineer as best he may in practice. This work, therefore, fills a real need. It is written with the presumption that the reader is familiar with methods of calculating stresses, and little space is given to this subject.

The book covers in detail riveting, roofs, plate girder bridges and pin connected bridges, and contains two general chapters on designing, estimating, manufacture, and erection. No claim is made to exhaustiveness in this treatment of the subject.

The author advises the keeping at hand, for reference, the larger standard works on bridge and structural engineering. But the work does attempt to supply, in compact form and in sufficient detail just such information as the engineer or draftsman needs in his daily work. The success with which this is done suggests the idea that the book is the result of years of practice on the part of the author. The work as a whole is simply an outline of good practice as recognized by all competent designers.

The general chapters on designing, estimating, manufacture, and erection contain much that is of value on office methods and equipment, and the ordering and handling of material, as well as information on shop work, inspection, and erection.

The book is well adapted to the needs of both the engineer and the draftsman.  
J. E. M.

**MUNICIPAL FRANCHISES. A DESCRIPTION OF THE TERMS AND CONDITIONS UPON WHICH PRIVATE CORPORATIONS ENJOY SPECIAL PRIVILEGES IN THE STREETS OF AMERICAN CITIES.** By Delos F. Wilcox, Ph. D. Engineering News Book Department, New York. Cloth;  $5\frac{3}{4}$  in. by 8 in.; 710 pages. Price, \$5.00.

This book is Volume I of a two-volume treatise, the second volume to follow in about one year. The object of the author is not to discuss the law of franchises, but to analyze and describe municipal franchises as they exist in actual operation in the cities of the United States.

In the introduction is set forth clearly all that is implied by the granting of a franchise to a public service corporation. The conflict between legalized monopoly and the public is dealt with in language that is at times eloquent and full of the swing of a campaign oration.

The author has endeavored to preserve neutrality and voice opinions of others as such, but it is plain that he does not believe in franchise values.

In Part II a most thorough analysis is given of pipe and wire franchises granted in American cities, with the lessons taught by experience. It is the first book in existence giving a study of this sort and is superior to magazine articles, which so far have been the principal educational material on a most important subject.

Volume II will contain parts 3 and 4, dealing with local transportation franchises and taxation and control of municipal franchises. The first volume is good reading.  
E. M. C.C.

**STRUCTURAL DETAILS, OR ELEMENTS OF DESIGN IN HEAVY FRAMING.** By Henry S. Jacoby, Professor of Bridge Engineering in Cornell University. John Wiley & Sons, New York, 1909. Cloth; 6 by 9 ins.; pp. 368. Many illustrations through the text, with some full page cuts and three folding plates. Price, \$2.25.

This is an admirable book and is well worth a place in the library of any engineer engaged in structural work.

With the great use, in recent years, of structural steel, and the more recent turn toward concrete, plain and reinforced, one is apt to overlook the fact that with these materials there is use for much timber work in erection, forms, etc., where the loads are such as to require careful planning and execution of the temporary work in timber framing to get good results in the complete and finished structures.

The author is known to many of the readers of this Journal as a member of the American Society of Civil Engineers, and also as an experienced and skillful instructor at Cornell University, and the book is welcomed on this account.

April, 1910

Chapter I, of 86 pages—18 articles—treats of Fastenings Used in Framing.

Chapter II, of 75 pages—16 articles—considers Joints Used in Framing.

Chapter III, of 72 pages—19 articles—takes up the subjects of Wooden Beams and Columns.

Chapter IV, 69 pages—18 articles—considers Wooden Roof Trusses.

Chapter V, 50 pages—6 articles—gives Examples of Framing in Practice.

Chapter VI, 23 pages—7 articles—covers Timber Tests and Unit Stresses.

The reviewer, in reading this excellent treatise in structural engineering, regrets that it was not at hand in his earlier studies and practice in his professional work, and feels that the wealth of statements, illustrations, suggestion, references, and other helps might have saved him much work.

In spite of the growing use of steel and reinforced concrete as great elements in modern construction, there is still the old great field of timber construction, where, for economic and other reasons, the other two materials are not available, and this book essentially points out the way to skillful and intelligent design in this material.

**ELEMENTARY COURSE IN PERSPECTIVE.** By Sherman M. Turrill, C. E., Assoc. Am. Soc. C. E. D. Van Nostrand Co., New York. Cloth; 5 by 7½ ins.; pp. 71; 16 illustrations and folding plates. Price, \$1.25.

A handy little volume has just been added to the list of text-books on perspective. Its author is a Civil Engineer, also a teacher, and it is evidently in the latter capacity that he has written the book, for it is arranged with the logical order and system which one would expect from an experienced instructor.

The book describes two methods of drawing in perspective—first, the method by orthographic projection; and, second, the method by scale. Each method is illustrated by examples in parallel and angular perspective, circles, and shadows. As the same examples are worked out by each method, the relative values of the different methods are brought out clearly.

A feature of the book is the system of lettering the perspective diagrams, which is very simple and clear when once understood.

The typography is fair, but the diagrams, which are well-arranged, lose much from the minuteness of the index letters, and the folding plates prophesy a speedy mutilation of the book under the strain of the usage such a book will get.

M. G. H.

**COST KEEPING AND MANAGEMENT ENGINEERING.** A Treatise for Engineers, Contractors and Superintendents Engaged in the Management of Engineering Construction. By Halbert P. Gillette and Richard T. Dana. The Myron C. Clark Publishing Co., New York and Chicago. Cloth, 6 by 9 ins.; pp. 346, including index. Price, \$3.50.

The book contains eight chapters covering the following subjects:

- I. The Ten Laws of Management.
- II. Rules for Securing Minimum Cost.
- III. Price Rate, Bonus, and other Systems of Payment.
- IV. Measuring the Output of Workmen.
- V. Cost Keeping.
- VI. Office Appliance and Methods.
- VII. Bookkeeping for Small Contractors.
- VIII. Miscellaneous Cost Report Blanks and Systems of Cost Keeping.

There are 184 figures, of which eight are half-tone cuts, the balance being devoted almost wholly to "Record Forms," etc.

The subdivisions and paragraphing of the book are clear and concise. Good clean type is used. The quality of the paper and binding are both very good. The page margins are a little wider than should be recommended for a book in the makeup of an engineer's library.

In reading this book it is with a degree of surprise that a subject ordinarily considered dry and uninteresting, can be made so interesting and almost entertaining as the authors have succeeded in making it. With this book available there is little excuse for engineers and contractors not becoming well posted on this important subject. As a matter of fact, it can well be made a part of the engineer's school training. It goes without saying that the contractor will gain in a still larger measure by a knowledge of the principles laid down. The book can be very strongly commended for consideration by the heads of departments in municipal work.

One of the most commendable objects which the authors have had in view was to show where the worker's interest in his tasks could be awakened and enlarged. Also the unmistakably correct principle of adequately rewarding the worker for his increased interest, effort, and output. That principle and practice applied to the great field of human wage workers would tend to vast and far-reaching benefits.

"The Primary Objects of Cost Keeping" as stated by the authors are two: 1st, "To enable a manager to analyze unit costs, with a view of securing the minimum cost possible of attainment under existing conditions." 2d, "To provide data upon which to base estimates of the probable cost of projected work."

The writer is going to take the liberty of offering the following, instead: To learn how to accomplish work on the lines of least resistance, and to know when it is being done along those lines, with the least expenditure of labor, time, and money, at the same time lifting the worker to a higher plane.

C. K. M.

INSPECTOR'S HANDBOOK OF REINFORCED CONCRETE. By Walter F. Ballinger and Emile G. Perrot. Engineering News, New York. Cloth, 4½ by 7 ins.; 66 pp.; 6 folding plates. Price, \$1.00.

This book has but three chapters. The first treats of Forms or Falsework: Box-shaped Forms, Knock-down Forms, Props or Shores, Steel Beam Girders, Column Forms, Cleaning, Wall Forms, etc.

The second chapter is on the subject of Reinforcement: Systems and Bars, Function of the Various Parts of the Reinforcement, etc.

The last chapter is on the subject of Concrete: Mixing, Finishing, Protection, Construction, etc.

An appendix contains tables and data on rectangular beams, with formulae for strength of rectangular beams, T-beams, and rectangular columns.

CONCRETE STEEL CONSTRUCTION. (Der Eisenbetonbau.) By Professor Emil Mörsch, of the Zürich Polytechnic, Zürich, Switzerland. Authorized translation from the third (1908) German edition, revised and enlarged, by E. P. Goodrich, consulting engineer. The Engineering News Publishing Company, New York. Cloth; 6½ by 9½ ins.; 368+IX pages; 360 figures in text. Price, \$5.00.

This work will be of considerable interest to reinforced concrete engineers and designers, because of the clear presentation of European practice. Much space is given to experiments in France, Germany, and Switzerland with no reference to American work. The discussions are full and the worked examples are plentiful. European legal regulations for the use of reinforced concrete are given, so that the reader becomes acquainted with the best foreign practice. The translator has retained the original nomenclature and use of the metric system, but the English equivalents are given wherever measurements are quoted, as well as in

all tables. Furthermore, a table of metric and English equivalents has been included at the end of the book. If the nomenclature of standard American books had been followed and the metric units abandoned, it would have helped the sale, because the work of the reader would have been lightened. The translation, therefore, is not so freely performed as the reader has a right to expect. This is practically the only criticism to make.

The book is divided into two parts, dealing respectively with *The Theory of Reinforced Concrete*, and *The Applications of Reinforced Concrete*. The theory has to do solely with columns, girders, beams, and slabs, while the practical section illustrates arches, etc., as well as buildings. In treating cellular bins and tanks the word silo is used, in spite of the fact that as used in America silo means a receptacle, generally in the shape of a tank or tower, for storage of green fodder to be fed later to live stock. In the book this definition is given, "Silos are bins for certain dry materials, such as grain, coal, cement, ore, broken stone, etc."

The translator has performed a great service to engineers unable to read German, and the publishers have given his work a neat dress. The book was written by an eminent man and for a number of years it has been considered as perhaps the leading one in Europe on the subject. As a practical book it can certainly be commended.

E. McC.

## LIBRARY NOTES.

The Library Committee desires to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

### MISCELLANEOUS.

New York Public Service Commission—

Comparison of Operation of the New York and Paris  
Subway Systems. By Robt. H. Whittier. Pam.  
History and Description of Rapid Transit Routes in  
New York City. Pam. Proceedings 1907-8. 3  
vols. Cloth.

Board of County Commissioners, Cook County, Ill.—

Third Annual Message of President to the Board. 1909.  
Pam.

Bernt Berger, New York—

General Specifications for Steel Highway and Electric  
Railway Bridges and Viaducts. Cooper. Pam.

Myron C. Clark Publishing Company, Chicago—

Diagrams for Designing Reinforced Concrete Structures.  
Dodge. Boards.

Cambridge Bridge Commission, Boston—

Cambridge Bridge Commission Report. Cloth.

Bureau of Statistics, New South Wales—

Official Year Book of New South Wales. Bds.

Gen. Grenville M. Dodge, Hon. M. W. S. E., Council Bluffs, Iowa—

How We Built the Union Pacific Railway. Dodge.

Engineering News Book Dept., New York—

Municipal Franchises. Wilcox. Cloth.

Inspectors' Handbook of Reinforced Concrete. Ballinger & Perrot. Cloth.

Steel Structures. Morris. Cloth.

Field Practice of Railway Location. Beahan. Cloth.

Bridge and Structural Design. Thompson. Cloth.

Tables and Diagrams for Obtaining the Resisting  
Moments of Eccentric Riveted Connections. Rexford. Cloth.

Michigan State Board of Health—

Annual Report, 1908. Cloth.

State of Ohio Highway Department—

Fifth Annual Report, 1909. Pam.

Frederick T. Barcroft, Detroit, Mich.—

Barcroft Appraisal Detroit United Railways, 1909.  
Cloth.

Architectural Record, New York and Chicago—

Sweet's Index, 1910. Cloth.

C. L. Strobel, M. W. S. E., Chicago—

The Second National Peace Congress, Chicago, 1909.

Reports of National Monetary Commission. 7 Pams.

Mr. C. M. Kurtz, San Francisco—

Modern Location of Standard Turnouts. Kurtz.

Allen Winch, publisher, Chicago—

The Western Blue Book and Buyers' Reference, 1909.

Prof. C. F. Burgess, M. W. S. E., Madison, Wis.—

The Strength of Alloys of Nickel and Copper with  
Electrolytic Iron. Univ. of Wisconsin, Bulletin  
No. 346. Pam.

April, 1910

- Board of R. R. Commissioners, South Dakota—  
20th Annual Report. Cloth.
- Virginia Geological Survey—  
Annual Report of the Mineral Production of Virginia,  
1908. Pam.  
The Cement Resources of Virginia, West of the Blue  
Ridge. Pam.
- Wood Preservers' Association of America—  
Report of Proceedings, Annual Meeting, 1909. Pam.
- Water Board, Brookline, Mass.—  
Annual Report, 1909. Pam.
- Sherman M. Turrill, Chicago—  
Elementary Course in Perspective. S. M. Turrill.  
Cloth.  
Proceedings of the Society for the Promotion of Engi-  
neering Education. Vols. 12, 13, 14, 15, 16. Cloth.  
Elements of Geodesy. Gore. Cloth.  
Geodetic Astronomy. Hayford. Cloth.  
Report of Commission on Additional Water Supply for  
City of New York. Cloth.  
Report of Board of Rapid Transit R. R. Commission-  
ers of the City of New York. Nos. 3 and 4. Pam.  
The Carnegie Foundation for the Advancement of  
Teaching. Pam.  
Various Pamphlets, Specifications, etc., for contract  
work, New York City.
- State Commissioner of Highways, Maine:  
Fifth Annual Report, 1909. Cloth.
- E. E. R. Tratman, M. W. S. E., Chicago—  
Proceedings American Water Works Association, 1909.  
Cloth.  
Illinois Geological Bulletin No. 12. Cloth.  
The Michigan Engineer, 1909. Cloth.  
Report of the Hudson's Bay Railway Surveys. Pam.  
Journal Cleveland Engineering Society, December,  
1909. Pam.  
Journal Railway Signal Association, December, 1909.  
Pam.  
Report of Isham Randolph on the Jones Island Harbor  
Project. Pam.  
Water Supply and Irrigation Papers, Nos. 236, 238.  
2 pams.
- GOVERNMENT.
- National Waterways Commission—  
Tabulated Statement Relating to Internal Waterways  
Improved by the U. S. Government to January 1,  
1910. Pam.
- U. S. Commissioner of Labor—  
23d Annual Report. Cloth.
- U. S. Geological Survey—  
Bulletins Nos. 396, 397, 400, 408, 410, 411, 413, 419, 421,  
424.  
Water Supply and Irrigation Papers, Nos. 236, 238.  
Mineral Resources, 1908. Vols. I and II. Cloth.
- Department of Commerce and Labor—  
Report of the Superintendent of the Coast and Goedetic  
Survey, 1909. Cloth.
- U. S. Civil Service Commission—  
12th Annual Report, 1894-5. Cloth.

- Interstate Commerce Commission—  
 Bulletins of Revenues and Expenses of Steam Roads  
 in the United States. Nos. 5, 6, 7, 8, 9, 10, 11. Pams.
- U. S. Commissioner of Education—  
 Annual Report for 1909. Vol. II. Cloth.
- EXCHANGES.
- Engineering Association of the South—  
 Transactions, 1908. Pam.
- Lake Superior Mining Institute—  
 Proceedings, 1909. Vol. XIV. Pam.
- American Electrochemical Society—  
 Transactions, 1909. Paper.
- New Jersey Sanitary Association—  
 Proceedings of the 35th Annual Meeting. Pam.
- American Society of Mechanical Engineers—  
 Year Book, 1910. Cloth.
- Canadian Society of Civil Engineers—  
 Transactions, January to June, 1909.
- American Society of Civil Engineers—  
 Year Book and List of Members, 1910. Cloth.  
 Transactions, March, 1910. Paper.
- Ohio State Board of Health—  
 Annual Report, 1908. Cloth.
- Massachusetts Board of R. R. Commissioners—  
 41st Annual Report, 1909. Cloth.
- Institution of Civil Engineers, London—  
 Proceedings, February, 1910.
- Institution of Electrical Engineers, London—  
 Journal, February, 1910.
- National Association of Cotton Manufacturers, Boston—  
 Transactions, Semi-Annual Meeting, 1909. Bds.
- Illinois Highway Commission—  
 Bul. No. 6, Modern Bridges for Illinois Highways.  
 Pam.
- American Water Works Association—  
 Proceedings, 1909. Cloth.
- Junior Institution of Engineers, London—  
 Transactions, 1908-9. Cloth.
- Roadmasters and Maintenance of Way Association of America—  
 Proceedings, 27th Annual Convention, 1909. Pam.
- Illinois Geological Survey—  
 Bulletin No. 12. Cloth.
- American Railway Bridge and Building Association—  
 Proceedings, 19th Annual Convention. Pam.
- Iowa Geological Survey—  
 Annual Report, 1909. Cloth.
- Association of Water Engineers, London—  
 Transactions, 1909. Cloth.
- PURCHASES.
- Concrete-Steel Construction. Mörsch.  
 Der Huette. 3 Vols.  
 Electric Power Plants. Weingreen.  
 Gas Engine. Hutton.  
 Sewage Purification. Cosgrove.  
 Telephonology. Van Deventer.

# WESTERN SOCIETY OF ENGINEERS

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1735 Monadnock Block, Chicago.

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## MEETINGS

Regular Meeting—First Wednesday evening of each month except January, July and August.

Bridge and Structural Section—Generally the second Wednesday of the month.

Extra Meeting—Third Wednesday evening of the month except July and August.

Electrical Section—Generally the fourth Wednesday evening of the month.

Board of Direction—The Tuesday preceding the first Wednesday of each month.

## NOTICE

From the dues of each member, \$2.00 is set aside as a subscription to the JOURNAL.

# Journal of the Western Society of Engineers

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VOL. XV

JUNE, 1910

No. 3

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## CHICAGO'S SMOKE PROBLEM.

By Paul P. Bird, Chief Smoke Inspector, City of Chicago.

*Presented November 17, 1909.*

I have prepared for the society a brief and very general paper upon the subject of Chicago's smoke problem. If I had attempted to write on a subject that was not one of general interest to the people of Chicago, or to this society, I would have endeavored to have gone more into detail, and written a longer and more complete paper, but I realized that this subject was of intense interest at this particular time, and that the only thing necessary to secure a good meeting was to write a general paper, and one that would be suggestive of discussion.

At the beginning of the present city administration, Mayor Fred A. Busse appointed a committee of eight citizens to advise him about Chicago's smoke problem, and also to decide on the policies and plans to be followed by the smoke inspector in his work. The committee was called the Smoke Abatement Commission and the gentlemen appointed were:

Thos. E. Donnelley, chairman

A. C. Bartlett

E. B. Butler

John V. Farwell

Frederick A. Ingalls

William V. Kelley

Bryan Lathrop

John G. Shedd

Mr. Ingalls has since resigned but the other seven members are still active in the commission's work.

Based on the commission's recommendations, a new ordinance was drawn up and passed by the city council on July 8th, 1907. The new ordinance created the present department of smoke inspection. Before this time, the smoke inspectors employed by the city were under the department of steam boiler inspection. The head of the new department is appointed by the Mayor, but the other members of the department are under civil service. The ordinance further provided that the head of the department and his principal assistants should be mechanical engineers.

The chief way in which Chicago's new smoke ordinance differed from the old one, and in fact from any similar ordinance in existence, was that it provided that before a new steam plant is built, or any

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alterations are made in an old plant that may affect the matter of smoke, the drawings for the new work or alterations be submitted to the Smoke Department, the designs approved and a permit issued for the work. That part of the ordinance which defined a violation and the fines therefor, remained the same as in the old ordinance.

The present smoke inspector was appointed in September, 1907 and Robert H. Kuss, chief assistant shortly afterward. It took some time to hold civil service examinations and to get the other members of the Department together, and it was not until the spring of 1908 that the organization was complete and the work really under way. Provision was also made to furnish the Department with engineering advice by the organization of a Board of Advisory Engineers. This Board was appointed by the Smoke Abatement Commission. The engineers appointed were:

A. Bement  
George M. Brill  
Jos. J. Merrill

Mr. Bement has since resigned and Stephen G. Hobert was appointed in his place. The Board has met in the Smoke Inspector's offices on an average of once in two or three weeks.

During the fall and winter of 1907, the Smoke Abatement Commission, Board of Engineers, and the writer, spent much time and study in formulating the policies and plans to be followed. It was appreciated that the problem was a difficult one. This is one of the greatest manufacturing cities of the world, getting practically all of its heat and power from a local soft coal that must be burned with great care and skill in order to prevent smoke. There were about 17,000 boilers, 13,000 smoke stacks and 5,500 high pressure steam plants and the City had allowed these plants to be installed without any intelligent or careful supervision over the features that effected smoke. The science had progressed far enough that in newly designed stationary plants, it was relatively an easy matter to produce a plant that could be operated without smoke, but this was not the case in the limited space available in a railroad locomotive or in a steam vessel.

It was the idea of those who studied the problem at this time, to so map out the work for the Department, that permanent and lasting improvement would be made along sound engineering and business lines, rather than to attack any particular offenders that might be in the public eye. It was further realized that the work would be largely a campaign of education and that the results would come slowly because in a great many cases plants would have to be practically rebuilt. It was also appreciated that the City could not afford to appropriate sufficient money to support a department large enough to complete a work of this magnitude in a short time.

As a result of the study of these conditions, it was decided that the Smoke Department should not only call the attention of the owner to the fact of the smoke, and insist that it be stopped at once,

but, that the Department should point out to the owner the reasons why smoke was being made and then give him sufficient time to correct the faults before suit was begun. When upon investigation it was found that a plant could be easily operated without violating the ordinance, it was decided that the Department should immediately bring suit if the smoke continued. If found impossible to operate a plant smokelessly and the owner did not at once act on the department's request that the necessary changes be made, it was decided that suit be instituted. But in general, suit should not be started when the offender was doing everything possible to stop it. The key note of the policy decided upon was co-operation between the city and the citizen.

Guided by these policies, the Department has been working for about two years. The down town district has received the most attention and in this part of Chicago probably the greatest improvement is seen. As far as the capacity of the Department would allow, work has been carried on all over the city. In manufacturing districts, on the railroads and on the river, the smoke has been considerably lessened. The Stock Yards district, for years one of the smokiest in Chicago, because of the Department's work has been greatly improved. The Railroads have co-operated splendidly with the City and undoubtedly have tried harder than any other class of smoke makers to stop their smoke. Today there are two or three railway terminals in Chicago that are probably making less smoke than any other railroads in the country using soft coal. This improvement has chiefly been brought about by discipline of firemen and engineers. The Department's greatest problem is with the river boats. The City has no control over the boiler and furnace equipment in these vessels as the Federal Government inspects such machinery. Therefore the Department's efforts have been directed toward obtaining the best operations possible with the equipment. These crafts all use Pittsburg coal. The Department has decided to change its policy in dealing with the tug boats and next season they will probably find it necessary to burn hard coal.

In general, the Department has found ready co-operation. No one apparently desires to wilfully or maliciously violate the smoke ordinance, but it has been necessary to bring suit in a great many cases, before the offender is brought to realize that the matter is a serious one. This work cannot be accomplished without a strong and relentless policy of punishment of violaters who fail to take advantage of opportunities offered them.

After two years of experience, the Department is now strengthening the policies adopted at the beginning. During this time, there has been a considerable change in public opinion, regarding the smoke problem. The chief asset that such a Department can have in any city, is a strong backing by the public, favorable to smoke abatement. This feeling on the part of the public is now very much

stronger than it was in the fall of 1907. Further, as the work has gone along from month to month, the smoke offenders of the city have had opportunities to correct their plants and of learning how to operate them without making smoke. Therefore, the Department is becoming more strict day by day and is excusing less smoke and bringing more suits, and the next two years should bring about very much greater improvement.

Many citizens display very selfish motives in connection with Chicago's smoke problem. The public wants a cleaner city, with clear skies and clean buildings, but the average individual wants every one to reform except himself. A man appears never to see his own chimney smoking, but his neighbors stacks, in his mind are usually bad nuisances. Many a man who complains the loudest about a laundry or school house near his home, or about the chimney near the window of his down town office, or about the locomotives of a certain railroad, owns a factory on Goose Island or in the Stock Yards that contributes a far larger amount of smoke to Chicago's atmosphere than the stack of which he complains.

The Smoke Department is often criticised for giving engineering advice to citizens about their power plants, and it is said that in consequence, consulting engineers are deprived of work which should rightfully come to them. The Department does not want to do this and the ordinance does not require that it should do it, but conditions seem to make it necessary. The average manufacturer or owner of a power plant knows nothing of mechanical and consulting engineers and their work. He does not realize that smoke prevention is an engineering subject and that all cases are not solved by the same formula. The usual manufacturer feels that he can buy a boiler and install it precisely as he would buy a wagon or a new machine for his factory. The reason for this situation is deep-seated and cannot be discussed here. Good engineering is needed in this work. When the plans for a new plant go through the Smoke Inspector's office or in those cases where a good mechanical engineer is employed, the task is simple. No time is wasted in discussing simple details, and when the plant is put in operation, there is some one available to look after it who is responsible and capable. However, about seventy-five percent of the cases that come up are not handled in this way and the Department, in order to facilitate matters, does give a good deal of engineering advice. There is great need for engineering in small plants, but today the engineers do not seem to get the work. The Smoke Department is continually suggesting and recommending that people put their plants into the hands of competent consulting engineers, but very little work is handled in this way.

#### DISCUSSION.

*President Allen:* The smoke question that we are to discuss this evening is evolutionary in its nature. The first thing that we try to make and the first evidence of industrial

progress, is the smoking chimney. When we see it on the prairie we know that business has started somewhere; when we see it on rails we know that transportation is on its way; but this is an instance of where a good thing sometimes gets to be too much of a good thing, and becomes an evil. We unfortunately get most of our light through the atmosphere. We also have to breathe the air and to look through it, and that makes it necessary for us, in the interest of public health and of civic duty and patriotism, to look after the smoke that we have taken so much pains to produce; and now, after the industrial development of Chicago has brought us so many smoking chimneys, so many steamers on the river, so many trains and engines at our many terminals, we are forced to go back and endeavor to suppress this evidence of prosperity and try to ride both horses at once—have business without smoke.

The present administration of the city has, it seems to me, taken a long step forward in the matter of scientific regulation of the smoke problem.

I have had occasion to say a number of times, and I believe it will bear saying again, that I conceive it to be one of the chief duties and best features of a society like this to bring up for discussion, public questions which have a bearing on engineering, or which are engineering in their nature. The question of smoke prevention is certainly one of these, and I am very glad indeed to see such a large attendance this evening, and to observe so much interest manifested. I think we ought to encourage the discussion of such questions in our meetings, so that engineers will be thoroughly posted on public questions, and will know how to vote when the time comes, or how to serve the public intelligently, if called upon to do so.

*Mr. Thomas E. Donnelley* (President, Smoke Abatement Commission): I do not think that I can say anything on the engineering side of this question which would not be very commonplace to you here, but I would like to say just a word about policy, and about the Commission itself.

When the present Mayor took office, the question of smoke prevention was brought before him by the *City Club*. The Mayor had an idea that this question of smoke was one which ought to have engineering treatment, and he thought it was a question that could not be handled by hard and fast rules. He accordingly decided that he would turn this entire matter over to a Commission of business men in whom he had confidence, and in this way take it entirely out of city politics. You know the question of smoke abatement has been bandied around from one administration to another through various smoke inspectors who were not engineers, and, whether it was true or not, there was a great

deal of talk of scandal connected with the office. The Mayor appointed this Commission of eight business men, of which I happened to be one, and being the youngest they made me chairman so I would hustle; he not only asked the Smoke Inspection Department to co-operate, but he turned over the entire department to this Commission.

Now, this is different from any other department in the city. The Mayor has never given us an order since this Commission was formed. He left to us the selection of the smoke inspector, who was a man that the Mayor had never heard of, and whom we ourselves had never heard of until we began to inquire for someone who was competent to fill this office. In whatever direction we went we heard of Mr. Bird. The Mayor allowed us to redraft the ordinance to suit ourselves, and made an appropriation four times as much as had been made before. I want to make that plain, because people in Chicago are constantly getting the idea that the Smoke Department is in politics; that it is under influences which have been strong in the city for a long time. This is a fallacy, and anyone who knows anything about city politics knows the power which aldermen and other people have, and how hard it is for the head of a department to turn down a semi-reasonable request of an alderman. Now, as I said before, the Mayor has turned this matter entirely over to the Commission, has asked us but one or two favors, which were so reasonable that they were granted immediately.

The newspapers seem to have overlooked or forgotten this fact, and they constantly mix the matter up with the old political regime of the Department. Every policy that has been carried out by the Department has been settled in meetings of the Smoke Abatement Commission. We, of course, are busy business men, although I am the least busy of them all. We have had meetings on an average of once every two or three weeks, and there is no phase of this question, from engineering to all kinds of policies, that has not been brought up before these gentlemen, and, after full deliberation, settled. Of course, we are not engineers, and in order to obtain independent engineering advice when complaints were made against the policy, as they always have been, we asked for a board of consulting engineers, and I think you gentlemen know who these engineers are. When a question, or plan comes up between the Department and an operating engineer, it is immediately referred to these engineers, who refer the matter back to us with a report.

I want to make these statements so it will be realized that we are trying to handle this thing in an absolutely direct way without any influences whatsoever. These Commissioners are so earnest in this matter that they decided from the very beginning

that they were going to treat themselves just the same as they treated anybody else, and one of the Commissioners is now being sued for making smoke on account of carelessness in handling his plant. I mention this so you may know we are showing no favoritism. Of course, when we started in, this question of smoke prevention was like a great many other things, and most people thought it was just another one of those periodical propagandas for excitement to do away with smoke. We have been in office two years but have not accomplished as much as we thought we would when we started. I believe, however, that we have made very substantial progress, and we certainly have found out now where we stand, and we are going to push it with a great deal more vigor than we have before. Most of the gentlemen present know that the prevention of smoke, even in a stationary plant, is not a question of a fixed formula. Some plants can be operated very easily, while others are operated with great difficulty. The result of that certainly calls for the use of discretion on the part of the executive officer of the city. Theoretically that is absolutely wrong. If an executive officer of the city is enjoined to do something by law, it is up to him to do it. Of course, if an executive officer assumes this discretion it makes him liable to all kinds of inferences against his honesty. Now, the Smoke Abatement Commission has established this policy and is standing firm on the use of discretion. We are not going to sue a man if in our belief he is doing everything he can to prevent smoke.

You know there have been quite a number of sensational articles in the *Tribune* recently, in which intimation was made that the smoke inspector had either been bribed or was derelict in his duty, because he did not sue the Illinois Central and the Chicago & Northwestern railway companies, and that he had sued two or three other plants in town very severely. We have had the very best co-operation that any of the roads could give us, on the part of the Illinois Central and the Chicago & Northwestern railway companies. When we were first organized we asked the presidents of these roads to meet us at luncheon, which they did. We told them that we wanted their co-operation. They promised to make, at their expense, any abatement that we asked; if apparatus appeared to be effective, they would install it, and would institute a severe discipline of their firemen, if necessary. Of course, some railroads have done better than others, but these two roads especially have helped us greatly. The C. & N. W. Ry. Co. has six men on the tracks all the time—smoke inspectors—who are teaching their firemen how to fire, reporting negligence and disciplining the men. The Illinois Central R. R. Co. were just as good for a while, but they have the

thing down so fine now that they don't need quite as many men today. We are not going to sue the Illinois Central and the Chicago & Northwestern railways if we believe that they are doing the best they can, and are disciplining their men; but if a man who has a stationary plant thinks that by "jollying" and writing us, and putting us off he can continue making smoke at his plant, we are going to show him that he cannot do this, and will sue that man until he makes up his mind to be a good citizen.

Perhaps at times we have been quite harsh, but we are going to be a good deal harsher. We have taken the stand that two years' time was reasonable enough for any man to fix up his plant, and the rule is, if a chimney is found smoking twice in thirty days, the owner (or operator) be sued. We expect to extend that rule to the outlying districts as fast as possible. We never begin suit, however, until we have sent one of our deputies to investigate the plant and talk the matter over with the operator; if he is willing to co-operate either by better operation, or changing his apparatus, we give him time; but when a man puts himself in an opposing position, or refuses to insist upon proper discipline of his firemen, then we sue him.

I want to make this statement, because I feel there are a great many people in Chicago who do not understand the situation. The Smoke Abatement Commission, by the authority and permission of the Mayor, are running this Department, and if you have any complaint to make against the Department, or think that you cannot get satisfaction and that the Department is inefficient, kindly make your complaint to us, and we will investigate your case.

*Mr. R. H. Kuss*, M. W. S. E. (Assistant Smoke Inspector): Out of modesty I should play a thinking part in this discussion, but it seems that honors are thrust upon people sometimes, because of the position they hold. In line with the paper itself, it is only fair to say that the Department has found it necessary to modify and change its policy from time to time. A large portion of the changes that have taken place have come about because of a lack of sufficient knowledge, in some cases, on the part of the people in the Department, and in other cases because of lack of knowledge among the engineers and others in the city, making it almost impossible, especially at first, to obtain a satisfactory method of handling the business through outsiders. It has been a big handicap to us not to be able to refer the particular problems, that are all different, to engineers in the consulting business. It has also been a handicap to us to be unable to educate the engineers in our own Department, where changes have been necessary, in a relatively short period of time. It

has taken us some time to find out just what is good engineering in smoke prevention. It is true that everyone can talk about smoke prevention, and, similar to the medical profession, it is somewhat easy to provide a remedy if you can diagnose the disease. Our trouble is that we cannot properly diagnose the disease. We cannot go into the details of the diagnosis ourselves to the degree that we can write the prescription, and the number of people that are competent to do that on the outside is very few. Fortunately their number is gradually increasing.

In regard to the policy of handling new work, we have undergone a few changes, and important ones, since the beginning of the work. Probably the most important thing that we have done is to come to a complete realization of the fact that to make any new installation safe, there must be a responsible person between the owner of the plant and the Smoke Department. There must be someone else besides the man who pays the bill for installing the furnace and the Department that holds him responsible. Put it in another way; we have concluded that a good furnace, after its installation, very often fails and continues to fail until it receives the attention of a good engineer. The causes of those failures are various. As a corollary to this statement, a relatively poor furnace, properly followed up by an engineer, will succeed in nearly every case. The follow-up work is a most important part with any furnace. In connection with this work, some of us have come to the realization that we are not perpetually to be connected with Chicago's Smoke Department. We realize that the information of smoke prevention must be disseminated so that the work can go on, no matter what becomes of the men that happen to be in the Department. If the work may not be done as well sometimes by outsiders, as by the Department, it is better that the experience should be gained by outsiders in order to insure the perpetuation of the good work. That, I think, is a good fundamental principle to work on.

Now, the consulting engineer cannot take the position that he can design furnaces—meaning particularly the hand-fired furnaces. It would seem to me to be folly for a consulting engineer to attempt to design the details of a furnace, even to the same degree that the Smoke Department did at first. The consulting engineer, however, has a very large field of activity in regard to the furnaces. He can determine the kind or type of furnace, adapted to a particular kind of work; he can select that furnace or one of that type, and leave the designs to a responsible apparatus company, and fix the responsibility on this company so he may be assured of competent follow-up work by them. That, I should say, is the proper way for a consulting engineer to proceed if he is not a specialist in furnace design.

To particularize a little bit on the mistakes that have been made, not only by ourselves, but by nearly everyone else, the one large fault that has appeared in every unsuccessful case has been

the lack of draught. By that I do not mean necessarily the available draught at the base of the stack, but more particularly the available draught for the furnace. In nearly every case of boiler setting designs we have found that the connection between the boiler exit and the breeching connection with the chimney was faulty. We did not pay as much attention to that as we should have done, but that is one of the places where you will find more mistakes made than anywhere else. Another mistake that is quite prevalent and is bound to recur, and can be corrected only when the furnace is finished and in operation, is that of a disproportionate grate, and the mistakes are usually made in the direction of having them too large rather than too small. The significance of this remark must become apparent to you when you remember that the usual statement made in regard to smoke is that the boilers are forced. Of course the City Smoke Department is not concerned with boilers, but with furnaces. We find that a large cause for smoke, when all other conditions are well designed is the replacements which occur in connection with boilers.

If you gentlemen will remember one little point in connection with this subject, I think you will agree that the criticisms that have gone out about the Smoke Department are just a little too harsh under the circumstances. There is not one good reliable source of information in printed form. There is not today a place where you can look for and read up on the subject of combustion that will give you any clue how to handle any particular problem. Now then, if there is to be a remedy to that state of affairs, it would mean that someone must be prepared to supply that information and properly arrange it. That will take some money. If there had been anything reliable on the subject at the start, we would be a year ahead of where we are now, but we had to learn in the school of experience, just like everyone else. I say the criticism should be modified, because of the lack of information in good form.

In connection with the same point, by having good engineering information available to the ordinary engineer, there would be a way to prevent repetition of error. One engineer will make the same mistake as another engineer, and he has no way of telling that it is a mistake until after his own experience teaches him. The Smoke Department can do much by putting that information in the proper shape. So far as we can, we are collecting and arranging the information as it comes to us.

*Mr. S. G. Hobert* (Smoke Abatement Commission): I do not know that I can add much to the paper or discussion as it stands. You have heard the outline of the department rather fully, and the chairman of our Commission has presented the status of the Commission. Mr. Kuss' discussion of some details and methods of requirement for progress is a good one. He

brought out one phase of the situation possibly, when he said that a good many of the plants which were only moderately well equipped were well taken care of in operation by good engineers, and that well designed plants have failed through faulty or careless operation. Speaking broadly, there are two important items or phases of the boiler and furnace proposition; that is, the design and the operation. As engineers, we are all interested in designing, and all helping towards designing. As operating engineers, many of us are doing our best to operate or to change the equipment which the owner has installed, and it is such work that to my mind offers large opportunities for our progress. Furthermore, the operators of the plant in the basement are usually drawn from wherever they can be drawn,—from sailors and dock rustlers, and that class of men,—so that we depend largely on the man who receives the least financial return for his work for the success of our furnace. It would seem that if concerted effort should be made to educate or uplift this class of labor, the effort would be amply repaid.

This morning I noted an editorial in the current issue of the *Engineering Record*, which brings to our attention the way they are handling this problem, to a certain extent, in Germany.

Smoke prevention is being combatted systematically in Hamburg by an association, now seven years old, called the *Verein für Feuerungsbetrieb und Rauchbekämpfung*. It is an organization of owners of power plants who recognized that it was to their pecuniary advantage, as well as the good name of their city, to obtain smokeless combustion. The association has been steadily increasing in influence, and now has 374 members, owning 1052 boilers and 148 other types of fuel-using plants. Many of these plants are not located in Hamburg, for the membership now extends from Finland to Alsace. The influence it has reached is shown by the fact that all the municipal boiler plants in Hamburg have been placed under its supervision, and the city pays it \$1,250 for this service. Its regular work is to inspect and test the boiler plants belonging to its members and to instruct the attendants in their duties. Such examinations during 1908 raised the efficiency of the plants from 12 to 20%. The work is done by a chief engineer, four assistant engineers, and four instructors.

Particular stress is laid on the good results which follow intelligent stoking, and the association has succeeded in introducing quite widely the bonus method of paying stokers. Over a third of the boilers in its charge are now provided with aspirators for taking the gas samples, on which the payments to the men are based. The bonus paid is 5% of the value of the fuel saved, for all percentages of  $\text{CO}_2$  over 8%, while the stoker is docked  $2\frac{1}{2}\%$  of the fuel lost when any hydro-carbon gases pass away unburned. The maximum bonus is fixed at 22 cents in a 12-hour shift and the maximum deduction at 17 cents.

The results of the association's work, in increasing boiler

economy and diminishing smoke, are noteworthy, and fully confirm the arguments made at intervals for more than a dozen years in favor of encouraging better stoking. A manufacturer will install an excellent power plant, buy good fuel, and then entrust the use of that fuel to men of little intelligence with absolutely no incentive to do their best. The heavy fixed charges and fuel bills for such a plant offer a particularly strong argument for encouraging the men by means of such a system as that of the Hamburg association.

This shows the difference between German methods and methods in this country, and I think Chicago is close to the head, in this country, in its efforts to suppress smoke. I think that if the members of this society could individually and collectively give some particular thought to this phase of the question in the development of the efficient operation of all plants in their charge, and in charge of engineers throughout our city, they could no doubt effect greater good and greater improvement than an equal amount of energy put into the financial end of the policy.

*President Allen:* So far the floor has been held by representatives of the smoke inspection side of the problem. I would like to hear from some of the manufacturers,—some of the people who have perhaps made smoke in the past,—and I want to call next on Mr. W. L. Abbott,—a gentleman whom we all know, who probably has had more coal burned under his supervision than any other engineer in Chicago, and who also has been one of the leaders and pioneers in the scientific burning of coal.

*Mr. W. L. Abbott, M. W. S. E.:* For thirty years, more or less, to my knowledge, the city has been endeavoring to suppress smoke, and it is only within comparatively recent years that any results have been obtained that have been worthy of the effort. It is true that during the early part of the city's experience in the attempt at smoke suppression, the atmosphere of the City Hall was not suitable for the suppression of anything, but at the present time I think it will be conceded by those who are acquainted with the gentlemen who are at present managing this Department, that the Smoke Inspection Department is now receiving intelligent supervision, is being courageously conducted, and is entirely unhampered. But with all this, it is difficult at first to understand why some results which are being obtained now should not have been obtained heretofore. I attribute this principally to the fact that formerly no thought and no supervision were given to the plants as they were being installed, and no attention was paid to them until the boilers were selected; the furnace was built with or without design, and a chimney began belching forth smoke into the atmosphere. Then the Smoke Department began its prosecution of the plant owner, who was handicapped with an equipment with which it would be

impossible to make steam without at the same time making smoke. Now, however, the smoke inspection department begins to suppress the smoke before the boilers are fired, before the boilers are set, possibly before the boilers are purchased, or at least before the furnace is designed. Thus no designs can go into effect until they have been passed upon by the engineers of this Department.

The effect of such a method of smoke suppression naturally cannot be noticed at first. Those chimneys which have been smoking will continue to smoke, if furnaces are so designed that the smoke cannot be prevented. It is only as new plants come in, one after another, that the diminution of smoke will be noticed, and it looks to me that the city must, as far as stationary plants are concerned, depend largely upon the general reconstruction and evolution of the stationary plants. The Department may, in its discretion, bring such pressure to bear upon coal users as will compel them to replace their existing furnaces with those of smokeless design. This I presume is being done, but it is something which cannot be done in a hurry, and is something which will have to be worked out with the boiler-users, by a very slow process. The Department, as has been mentioned by Mr. Donnelley, is allowed and assumes to itself the right to exercise a wise discretion in the enforcement of the ordinance. They might, for instance, discriminate between a plant which burns, we will say, one hundred tons of coal a day and makes some smoke, which might be objectionable, and a plant which would burn ten tons a day and makes the same amount of smoke, while the former would be making only one-tenth the amount of smoke with the same amount of coal that the smaller plant was using.

Concerning the experience which is being had in Germany in the suppression of smoke which Mr. Hobert referred to, it occurred to me that the association must be rather more for the improvement of boiler efficiency than for the suppression of smoke, from the fact that they pay firemen according to the percentage of carbon dioxide in the gas. The presence of carbon dioxide in flue gas indicates that coal is being burned with a less supply of air, and might indicate, and in some cases does indicate, that it may be burned with more smoke; also that reductions are made in proportion to the percentage of hydro-carbon gas which is found in flue gas. I have had some careful and elaborate searches made for the presence of hydro-carbon gases in flue gases, and although I was quite certain that they existed there, they were so elusive that they avoided every chemist that I put upon the job excepting one; he sent me a report which indicated that he found about four times as much hydro-carbon in the flue gas as existed in the coal itself!

*President Allen:* I think Mr. Abbott's point is well taken, and I have no doubt that the members of this society will read the paper that he referred to with a good deal of interest.

The name of that association would indicate that they were after smoke also.

*Dr. W. F. M. Goss, M. W. S. E.:* I am deeply interested in these very practical suggestions, explanations, and descriptions, and if I felt sure that I would not break the thread of this practical discussion, I would like to read a little romance, inasmuch as I have had pleasure in writing it. I present this, because it is in striking contrast with the practical considerations which have already been presented. If you regard it as emanating from academic halls, perhaps you will excuse it. Years ago the people of Chicago demanded that the atmosphere about them should be free from the taint of sewer gas, and that their water supply should be unpolluted, and they started a great movement which resulted in the present drainage canal. They have in the past demanded that the city, at night, be freed from the danger and inconvenience of dark streets, and light has been given them. These were demands which in their time were reasonable and right, and they prevailed. The question now at issue is whether the time has come when this great community may properly ask that it be freed from the nuisance of atmospheric smoke. The situation is so full of possible and actual misunderstandings that it seems to me a discussion along broad and comprehensive lines will not fail to be profitable. I propose, therefore, briefly to discuss the question as to what must be done to free the atmosphere of Chicago from smoke pollution.

Chicago can be made smokeless only by the absolute prohibition of soft coal burning under every condition which will not admit of perfect combustion. Interpreting this statement in the light of present-day possibilities, it means that soft coal must be banished from the homes of the city,—it cannot be used as a fuel for domestic heating; that small boiler plants, now so numerous in every part of the city, must in most cases be abolished; that industrial fires, large and small,—the fire of the forge and the furnace,—must in many cases take new forms; and that railroad operation within the territory defined must undergo a great change. Before such a prohibition can become practicable, a condition must be developed which will enable all classes of people to supply their needs, not merely as effectively as they now supply them, but with such added convenience as may be permitted by the natural development of the arts during the transition period. The accomplishment of all this will involve a vast amount of capital. It need not all be supplied in a day, however, and in this respect the problem is perhaps not more difficult for the present generation than other problems in municipal upbuilding which have been met and solved by preceding generations have been for them. It is true that the interest on this invested capital, and possibly some increase in operating cost arising from a new order of things, will constitute a tax on the community, but so also have costs arising from every form

of betterment by which a prairie has been converted into the present city of Chicago. Improved streets, water supply, sewers, lights, transportation facilities, and parks are all matters which have cost heavily; but so far as such improvements have been well directed and faithfully executed, no present-day citizen who lives in the enjoyment of them regrets the action of a preceding generation in providing them though he is taxed to pay for and to maintain them. It must be remembered that so long as men prosper, their homes will continue to improve, and that which people really want they will ultimately be willing to pay for. It is not unlikely that in the logical development of Chicago's plans for betterment, her next great step should be one which will clear her atmosphere.

The steps preliminary to the development of a smokeless Chicago, so far as they can be interpreted by our present knowledge of the art, involve the establishment of great public service stations at various points throughout the city, which, because of their size, may be readily equipped to burn without smoke the coal which nature has placed at our door. From each of these stations there will be sent out throughout the zone assigned, light and power in the form of electricity, heat in the form of steam or hot water, and fuel in the form of gas; all the stations together completely supplying the needs of the entire city. In the design and upbuilding of these plants with their attached distributing systems, it will be possible to so adjust the different classes of equipment to the demands which will be made upon them, as to insure high efficiency in operation. This fact, combined with the large scale upon which the operations would proceed, should make it possible to supply the needs of the consumer, small or large, either with heat, power, or fuel at costs in no case materially larger than those which must be met under present-day conditions. If, for example, under the new conditions, the small manufacturer is required to pay more for the gas fuel to sustain his fires than he now pays for coal, his lights and his power will undoubtedly cost him less, and the net increase in cost, should there be an increase, would constitute his share in the cost of maintaining a smokeless city. As a part of such a great scheme of development would come the electrification and probably also a good deal of relocation of the railroads, a matter which because of its magnitude should be developed through treatment by zones, rather than by individual roads.

Enough has been said to disclose the extent of the problem. It should be clear that its solution is not to be reached by the electrification of any one railroad. It is not, in fact, primarily a problem for the electrical engineer, though such engineers may have an important part in its solution. It is rather a business problem, a problem which will ultimately involve expenditures of greater sums of money than any municipality has ever yet expended or asked for. Can Chicago formulate the necessary

plans, can she bring order out of conflicting interests, and can she safely and satisfactorily administer so vast an enterprise either as a municipal undertaking, or through the coöperation of great public corporations? These are the great questions, and satisfactory progress in the development of a smokeless city can not be made until they have been carefully studied and answered. They are questions, the working out of which belongs in a peculiar way to Chicago, for at no other point are the great soft coal fields of the Middle West tributary to so large a population. The coals of these fields are Chicago coals; she must use them, and nothing is more fitting than that she should show the world how to use them successfully and well. It is not too much to expect that a community which, in the lifetime of living men, has grown from a frontier village to be one of the world's great cities; which, through business pluck and engineering skill, has overcome peculiar difficulties in the disposal of sewage and in maintaining the purity of its water supply; and which, through the enterprise of its builders, has created the modern office building, the advent of which is so rapidly changing the aspect of cities, should demonstrate for itself and for posterity the world over, the practicability of burning the coal which nature has supplied without polluting its atmosphere.

*President Allen:* We wish to extend the thanks of the society to Dr. Goss. In opening the discussion I made some remarks as to the privileges and the duties of an engineering body, and I would like to add that we want to find the universities and the colleges contributing their ideas to this work, and I think the contribution of Dr. Goss is very important as dealing with the question in a large way. He sets a mark for us to aim at.

*Mr. Wm. Wilbraham* (of Montgomery Ward & Co.): I regret that I shall not be present Wednesday evening, on the occasion of the discussion of the smoke problem in our city. At the same time, lest my absence should be misconstrued, I desire to express my appreciation of the work in general and of the personal work of the chief smoke inspector in particular.

I have been a chief engineer in Chicago under many and various administrations, and have been in a position to observe how others have handled the smoke problem before, and how it is now being handled. While perfection has not been reached, more has been accomplished than is generally realized. This has been by hard work and by establishing a spirit of coöperation between the smoke inspector and the smoke offenders.

There have been occasions when the smoke inspector has deemed it necessary to warn me of the necessity of taking more care in firing, and through these warnings I have often been enabled to find out what was the cause of our shortcomings and have been able and glad to rectify them.

I think this is a proper course, and one that should be pur-

sued where results are desired; hence I give him my heartiest support in his efforts to make a cleaner and better Chicago.

*Prof. G. F. Gebhardt*, M. W. S. E. (By letter): In connection with his educational work at the Armour Institute of Technology, the writer has had the unusual opportunity of coming in very close touch with the work of the Smoke Department, and can find nothing but the highest praise for the meritorious work done during the past two years. The policy of the Department, in vigorously prosecuting flagrant violators of the smoke ordinance, and in educating, not persecuting, the unwilling offenders, is the only practical way of attacking the problem. Criticism of the Department for offering engineers advice is ill placed and shows a selfish disposition on the part of those making the criticism. Large plants can well afford the services of a competent consulting engineer to look after the details of the furnaces and settings, but John Smith, who wishes to install a 50 HP. boiler in his laundry, is apt to find the cost of such services out of all proportion to the sum invested. It is the small plant which is usually the most obstinate offender because of faulty installation, and it is this class of plant which is most benefited by the advice given gratuitously by the smoke department.

Smokeless combustion is not as readily effected as is popularly supposed, and a smokeless chimney does not necessarily indicate an efficiently operated boiler plant. If the formation of objectionable smoke was productive of a heavy fuel loss, there would be very little need of a Smoke Department. The average power plant owner is after the almighty dollar, and if a smokeless chimney meant large returns to him, he would be the first to insist on smokeless combustion. But, unfortunately, a chimney may belch forth dense clouds of smoke and apparently be productive of satisfactory furnace economy, and it is for this reason that the average power plant owner is lax about the prevention of objectionable smoke. Touch his pocket-book and he responds at once. Since the Smoke Department cannot touch the pocket-book of the average offender by advocating smokeless combustion as a means of effecting economy, it naturally resorts to the next most effective weapon, the law-suit.

*Mr. A. Bement*, M. W. S. E.: The smoke problem is one in which I have been interested for a number of years. In general, agitation against smoke and a smoky condition is based very largely upon grounds of public health, damage to merchandise, injury to clothing, and a foul atmosphere, any or all of which reasons are sufficient; but in my practice as an engineer it has been found that the economical use of fuel and a smokeless combustion go together. If we obtain the condition which ensures maximum economy, smoke will necessarily cease, for which reason I require no other justification for the following:

This feature of economy is one that is not properly appre-

ciated. Many citizens feel, when asked by the Smoke Department to install the better class of furnace apparatus, that they are making a sacrifice to "satisfy the department," which is an erroneous view to take of the matter.

A very large portion of the smoke trouble may be eliminated by the employment of mechanically operated stokers, and a law, requiring their use in steam power plants of even very small size, is not only justifiable but desirable from the standpoint of economy. For a number of years many engineers have believed that it did not pay to install stokers in small plants, and in arriving at such conclusion they assumed that hand-fired plants would be operated in a theoretical manner, leaving out of account absolutely the fact that they are seldom or never so operated. In my experience in attempting to introduce proper methods of operation in such plants, I have many times been impressed with the desirability and advantage of stokers as a means of securing the result sought for but so difficult of attainment from hand-firing.

The necessity for a sufficient draft is something of the very greatest importance, and is a matter to which Mr. Bird continually directs attention. Chimneys, especially of smaller plants, are almost universally too low. In my opinion, a city ordinance should be enacted specifying the height of chimneys as well as requiring the use of mechanical stokers. The city, by ordinance, demands the use of plumbing fixtures embodying certain characteristics, and that they be ventilated in a prescribed manner. It is just as essential that the same consideration be given to the very important matter of chimneys and methods of burning fuel.

There has been much general talk of the desirability of a popular educational campaign for the purpose of showing people how to devise and install smokeless furnaces, by means of the publication of descriptive matter or personal advice on the part of smoke department officials and other interested bodies. It is my experience, however, that the most effective campaign of education is one which will convince the smoke offender that continued violation will result in enforcement of the city ordinance. Frequent efforts have been made to induce operatives of boiler plants to manipulate fires in a smokeless manner, and the problem has appeared very difficult of solution and sometimes well nigh hopeless, but in some of these very instances, when the smoke inspector became a serious factor, I have been interested and sometimes surprised to see that these chimneys immediately became smokeless. Thus, the result striven for by the engineer with only indifferent success, seems to be automatically secured when the fear of a fine and punishment hangs over the offender.

Within recent years there has been a disposition on the part of certain portions of the general public to expect and demand that Smoke Department officials act in the capacity of consulting engineers, offering advice and plans for furnace apparatus

which could be employed as a cure for smoke evils. In cases where this demand has been complied with, the result has been unsatisfactory, because, in the opinion of the public, the Department becomes responsible, in a measure at least, for the operation and smokeless performance of the design, and the owner feels released from liability. Formerly, smoke inspectors were not engineers, they were administrative officials; but the demand on the part of the public for men with technical knowledge in such positions may be met by an endeavor to help the public in engineering matters, which would result in harm rather than good. Personally, I consider that a smoke inspector should be an engineer, but that he should employ his engineering knowledge for himself and for the business of his office and not for the service of individuals.

The matter of economical administration of a Smoke Department is an important subject. No Department official ever feels that he has a sufficient number of inspectors to observe all of the offending chimneys, and he is compelled to continually inform complainants that it is impossible for him to watch certain chimneys as they think he should. Under past and present conditions there is practically no limit to the number of inspectors required, because as soon as it is known that the inspector is not watching a chimney, it is quite liable to smoke up. The result is that chimneys must be continually watched and offenders frequently notified. Now, whether their chimney is smoking or not would be apparent if the interested party took the trouble to step outside and look at it. They, themselves, may be their own smoke inspectors if there is sufficient incentive, which would be secured by more severe punishment in the levying of heavier fines. In this connection, a new instrument devised for the purpose of making an automatic record of smoke, has been announced. It is connected to the chimney so that a sample of the gases pass through it, making a record on paper upon which hours and minutes are printed. In this way the owner or manager may each morning see a record of the previous day's performance and know at what time smoke was emitted, or may have proof that there was no smoke. If offenders knew that they would be subject to a large fine they would exercise greater care, but with fines of only \$10.00 or \$15.00 they can afford to take a chance. A vigorous and positive enforcement of the present, or, if necessary, a better law than we now have, would result in bringing the inspection work within the capacity of the staff of the Department. I do not, however, wish to appear as an advocate of drastic or unreasonable measures, as the opposite has been my position for a long time. I consider that people, in individual cases where circumstances justify, should have ample time to correct their conditions, but at the expiration of such period, they should be expected to cease making smoke.

There has been an enormous improvement since the time im-

mediately preceding the Chicago World's Fair. Those who recall conditions during the years from 1880 to 1889, will remember that on a Monday morning in winter time it was so dark down town, from the pall of smoke hanging over the city, that lights in offices, stores, and factories were required until noon. Those who have in recent times observed the tremendous volumes of smoke issuing from the chimneys of the power houses of the South Chicago City Ry., at South Chicago, and the old Calumet Ry., at Burnside, may realize what Chicago once was, when every chimney tried to excel its neighbor in advertising that Chicago was, what some of our old-time friends would call, an "industrial city." At the present day we burn six or eight times as much coal as they did and produce very much less smoke. The reduction from stationary boiler plants has been brought about through improvement in apparatus and method of operation; that from steam shipping, to a loss in marine business due largely to inadequate harbor facilities. The only class of service which has shown an increase in volume of smoke is that of steam locomotives and domestic chimneys, for, as the city has grown, each have increased in the same ratio without being accompanied by proportionate improvement.

Chicago is the largest soft coal burning city in America, one of the largest in the whole world, and if smoke today were made in the old fashioned way, it would be necessary on week days to resort to our electric and gas lights, and we would require about four times as many laundries as we do now. This does not imply that we should be satisfied with things as they are, but that if so much has been accomplished the remainder of the remedy may be effected. A point has now been reached where it seems necessary to take account of the part our neighbors have in producing our smoke nuisance. The refinery of the Standard Oil Company, at Whiting, Indiana, is the largest individual offender in our locality, but this city has no jurisdiction there. The state has given the city power to legislate one mile beyond its borders on land and three miles on water, but Whiting, while it borders the limits of the city, is in another state. In the near future, owing to the rapid growth of population in the northwestern corner of Indiana, steps will be taken to enforce smoke regulations in that territory, but under present conditions we are in a defenseless position as far as that locality is concerned. Another example of this character has been met with in New York. Across the Hudson River on the Jersey side, an extremely smoky chimney gave great trouble on upper Manhattan Island. Not only was a very serious nuisance created there, but also on Long Island, the smoke crossing Manhattan and the North and East rivers. These examples illustrate the necessity for federal control of the smoke nuisance, also the desirability of a national society for the suppression of smoke.

The larger cities have their own departments, but smaller cities and towns are unfortunate in not having the incentive or ability which would enable them to institute the work. Cincinnati, Ohio, is an example, being the smokiest city in the United States, and even it might be brought to a realization of the possibilities of smoke suppression. Another example is that of San Francisco, oil being the fuel used in power plants, and there are only two smoke producers,—one a boiler plant using, in the crudest possible manner, a residue from oil gas-making process; the other, the works of the Standard Oil Company at Point Richmond. These two institutions defile the atmosphere and obscure the view for miles. There are other examples of this character in different parts of the country which indicate the possibilities before such a society.

Another phase of the problem which as yet has received but limited attention, is that of smoke made in the evening and at night.

In the work of improvement in Chicago, the efforts of two different bodies of citizens occupy a prominent place. It may be well to briefly outline the development of smoke suppression work in this city, according to my recollection.

From 1889 to 1893 Andrew Young, chief sanitary inspector of the Board of Health, in connection with other duties acted as smoke inspector. In 1891, the Society for the Prevention of Smoke was organized with the following officers: Bryan Lathrop, President; E. J. Phelps, Secretary, and C. F. White, Engineer, with an office in the top of the Monadnock Block on the north front. This society conducted its work with funds contributed by various citizens, employed its own legal talent, and prosecuted offenders in court as occasion required. This campaign developed some amusing features; for instance, Mr. Lathrop one day met the late George M. Pullman, who said, "See here, Lathrop, you are using that \$500.00 I gave you to prosecute me with." Mr. Lathrop replied, "Yes, certainly, Mr. Pullman, we are; that is what I got it for." After about eighteen months, owing to lack of funds due to approaching financial depression, the society's work came to an end. Much, however, was accomplished, not only during its period of activity, but afterward. The *Chicago Tribune* also took a very active part in this campaign.

This was the period just prior to the Chicago World's Fair. There had been a great amount of new development, many large steam plants had been built, and others were in process of erection. Some of these were provided with plain grates for hand firing, and had coal been used it would have resulted in a great increase in smoke, but fuel oil was cheap at that time and in use in a large number of these plants; thus it became an active agent in smoke prevention. The citizens wished the beautiful "White

City," as the Fair was termed, to be clean, and it will be recalled that oil was the only fuel used at the Exposition.

In 1893, F. U. Adams was appointed smoke inspector of the Department of Health, which office he held until 1895, when he was succeeded by Daniel May, his term expiring in 1897. From this time on the *Chicago Record Herald* became an important factor in the campaign.

In 1897 the smoke inspector's office was merged with that of the city boiler inspector. John C. Schubert was appointed and held office until 1907, when he resigned. This brings the history up to the present administration.

During the last year of Mr. Schubert's term in office, there was a decided expression of public opinion in favor of more rigorous enforcement of the ordinance. The City Club, through a committee, of which Slason Thompson was chairman, began agitation, which was continued under the chairmanship of Thos. E. Donnelley, who succeeded Mr. Thompson. The Club then engaged Robert H. Kuss, as engineer. At about this time, Fred A. Busse, who had taken his seat as mayor of the city, appointed the following Commission, which met in his office at 2 o'clock on the afternoon of May 16th, 1907:

Edward J. Brundage,	Corporation Counsel.
John J. Hanberg,	Commissioner of Public Works.
Joseph Downey,	Building Commissioner.
Dr. W. A. Evans,	Commissioner of Health.
Victor Elting,	President of the City Club.
T. E. Donnelley,	Chairman of the City Club Committee on Smoke Suppression.
John C. Schubert,	Chief Smoke Inspector.
Frank Hamlin,	Attorney for the Civil Service Commission.
A. Bement,	Consulting Engineer.
Wm. Holabird,	Architect.
John G. Shedd,	President of Marshall Field & Co.
Robert H. Kuss,	Engineer for City Club.
Edward B. Butler,	President of Butler Bros.
F. S. Peabody,	President of Peabody Coal Co.
W. T. Delihant,	President of Standard Washed Coal Co.

At this meeting Mr. Kuss acted as secretary, and the minutes of the meeting are doubtless among the records of the City Club. After remarks by nearly all of the gentlemen present, a committee was appointed to devise some plan of action. Mr. Butler was made chairman, and, if I remember correctly, the committee was composed of three members of the Commission. This committee did not report to the Commission, for which reason no further meetings of the Commission were held.

The committee then enlarged its membership as follows:—

Thos. E. Donnelley, Chairman,  
 Frederick A. Ingalls, Secretary,  
 A. C. Bartlett, Wm. V. Kelly,  
 E. B. Butler, Bryan Lathrop,  
 J. V. Farwell, John G. Shedd,  
 Mayor Busse, Ex officio.

Later, it reorganized as the Chicago Smoke Abatement Commission with Mr. Donnelley as President. Plans were then formulated for the organization of a new Smoke Department, in connection with which a board of consulting engineers was decided upon. After plans were completed an ordinance was introduced in the City Council, at its meeting of July 1st, creating a department of smoke inspection, the head to be known as the smoke inspector, to be appointed by the Mayor, and who must be a mechanical engineer; also creating the position of assistant smoke inspector with the same requirements as to qualifications. It was also provided that the Mayor, at his discretion, may appoint a Smoke Abatement Commission of eight members, and that the Commission may name a board of consulting engineers, as well as make other provisions. This ordinance was passed by the Council at its meeting held July 8th, 1907.

The organization as effected, with salaries, is as follows:—

ORGANIZATION AND SALARIES OF NEW DEPARTMENT.

Smoke Inspector .....	\$ 4,000	per annum
Assistant Smoke Inspector .....	3,000	" "

Deputies—

4 at \$1,500—\$6,000	
4 at \$1,200—\$4,800 .....	10,800 " "

Assistants—

5 at \$1,250—\$6,250	
5 at \$1,000—\$5,000 .....	11,250 " "

5 Clerks .....	4,500	" "
1 Stenographer .....	1,000	" "

Total .....	\$34,550
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The old organization which it succeeded, follows:—

ORGANIZATION AND SALARIES OF OLD DEPARTMENT.

Smoke Inspector .....	\$ 2,400	per annum
7 Assistants .....	8,400	" "
One-half time of clerk at \$1,200 per annum....	600	" "
One-third time of Stenographer at \$1,000 per annum .....	334	" "

Total .....	\$11,734	" "
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The smoke inspectors—Mr. Bird and assistant, Mr. Kuss—

were selected by the Commission and appointed by the Mayor. The consulting engineers were requested by the President, on behalf of the Commission, to serve as advisers to the Commission and smoke inspector when called upon. This Board, however, while acting as requested, did not organize until after my resignation, when Mr. Brill became chairman. The compensation of the engineers is \$10.00 per meeting, as provided for in the ordinance.

The work under the direction of the Commission has been highly successful. There have been comparatively few suits brought to trial considering the results obtained, and the Department appears to be making more friends than enemies. Soon after Mr. Bird's appointment, he addressed the local chapter of the American Society of Heating and Ventilating Engineers, at which meeting I was present, and there appeared to be an undercurrent of feeling doubtful as to the outcome, and a fear that strict enforcement of the law would entail hardship and injury to their business. He again addressed the same organization a few days ago, on which occasion I was also present, and the feeling seemed to be quite different. The expressed sentiment in the discussion was, that through his enforcement of the law, he had helped them out of many troubles.

Mr. Bird has worked hard in his position, has devoted much time and energy to the work of smoke suppression, and I think he is entitled to the thanks of engineers and the community in general.

Before closing this already extended discussion, I would make two suggestions, one having reference to the Commission, the other concerning methods of the Department.

The advisory engineering talent, I believe, is in the wrong place; it should be in the Commission, the Board of Engineers being of limited value. It must be remembered that the head of the Department is an engineer, also his assistant, while the Commission is without engineering advice in its own organization, yet many of the problems are essentially engineering ones. I think that the personnel of the Commission should embrace at least one engineer. True, the Commission may call in the Board of Engineers and ask its opinion, but the engineers are in no position to take the initiative so necessary in matters of essentially an engineering character. Thus it would be an advantage to have an engineer on the Commission.

I believe, also, that at least one member of the Commission should be a city official. It may be remembered that the city is the largest single individual violator of the ordinance, as it operates several hundred school houses, a large number of water pumping stations, and at the time the Commission was formed, a considerable number of electric lighting plants besides other boiler installations, all of which presents a serious prob-

lem, and it should be an assistance to have the help of some member of the city administration. I have in mind the Dynamite Commission appointed by the Mayor, consisting of thirteen members, among which are six engineers and experts and six city officials.

With reference to the work of the Department, I think a classification of stationary steam plants is desirable. For example, let it be assumed that four classes be established:

No. 1 would embrace such apparatus as could be depended upon to be smokeless, independent of the care received. An example of this character is in the electric power house at Harrison Street bridge.

No. 2. Such apparatus as with reasonable care in operation would be smokeless; for illustration, such as the Murphy stoker or Hawley furnace.

Class No. 3 would embrace furnaces which require reconstruction or improvement before they are in suitable condition to be transferred to classes Nos. 1 or 2.

The final class, No. 4, to embrace those plants in such condition that the only remedy is in the abandonment thereof, or entire rebuilding; as, for example, the two beforementioned antiquated street railway power houses in the southern part of the city, now on their way to the scrap heap.

The use of such scheme of classification would tend to the more thorough establishment of the work, and would be instrumental in developing a more definite understanding and realization among plant owners.

The present law I think should be given a very thorough and competent revision and the sooner it is done the better. In fact if we could have had some years ago, supervision of the installation of new plants as we have it now, some very expensive and troublesome mistakes would have been avoided. It is therefore desirable to prevent in the largest possible measure a repetition of past experience, and to make the law as comprehensive as possible, as we may not always have the present head of the Department or the Smoke Abatement Commission.

*Mr. P. M. Chamberlain:* There is one phase of the problem to which sufficient attention has seldom been given, namely that in relation to economy. It is difficult to drive people to spend money unless there is some direct compensation. If they find that it is cheaper to correct their smoke evil than to pay fines, it is quite likely that they will make the attempt. If, however, they find that after spending considerable money they are still in a position to be fined for smoke violations, they are very justly in a sensitive state of mind. Unfortunately there are quacks and anti-smoke fakirs, who, capable of presenting a plausible and convincing story, can find victims. The basis for persuading the violators of the smoke ordinance should be, in the opinion of the writer, that of economy. While it may be true

that a small amount of smoke is not necessarily indicative of important heat losses, in the great majority of cases the presence of excessive smoke is attended with very great losses from other causes. There are concerns and engineers in Chicago who are reliable and competent to advise fuel users so that their outlay instead of being an expense will be a good financial investment.

Regarding the Smoke Department's position in giving engineering advice, it seems to me that it would be impossible for them to have achieved the results that they have already achieved had they not done so, but it occurs to me in the light of Mr. Kuss' remarks, that in the absence of literature covering the field of smoke prevention and of proper combustion, it would be a very proper and most valuable field for the Smoke Department of Chicago to enter; that of giving the public, more particularly to the engineers as being better prepared to receive and digest it, the results of their experiments, for the Smoke Department has experimented and must continue to experiment. They have acquired information which they did not have before. If this information can be disseminated among all the intelligent engineers of Chicago, it will aid greatly in what we are working for. It seems to me entirely proper for the Smoke Department to issue bulletins covering, if not the entire science, at least an attempt at a digest of the subject of smoke abatement and fuel consumption in isolated cases, with as much of the data as possible. In this way their advice and information would reach a very large number of people and would seem to me to be productive of most excellent results.

*Dr. W. A. Evans*, (Commissioner of Health): The administration of the Health Department is surpassingly interested in the question of air pollution. The City of Chicago has spent more than \$50,000,000 to prevent pollution of its water supply. Our interests, public and private, at the expenditure of much more than that sum, have gone through a campaign for a pure food supply, the most extensive of which was the great world-wide campaign that we had a few years ago for purer meat supplies. Pure food is of course of vital consequence, and pure water is of vital consequence, but pure air is of infinitely greater importance than either of these. I think we could not find anywhere a man who would not admit that these great expenditures for the public welfare have been well disbursed.

In 1891 our death rate from typhoid fever, the most important water pollution disease, was 175 for every 100,000 people living in the community. We feel quite certain that this year it will fall to 11, and possibly to 10. That represents quite a saving, not only in human lives but also in money, and while it is very well worth while, it is my firm conviction that a campaign along adequate lines for the purity of the air will show much greater results in the saving of human lives and infinitely greater re-

sults in the saving of money and providing for the material welfare of our people.

The burning of coal results in several products, and various products that are concerned both with the coal itself and with the burning of coal, have been mixed in public consideration with the harm or lack of harm from the burning of coal. When coal is burned, as a result of improper combustion some part of the unburned carbon is discharged into the air, and along with that there is volatilized a fairly considerable mass of volatile oils and volatile substances. There is oxide of sulphur in that coal, and the carbon is turned into two chemical compounds, carbon monoxide and carbon dioxide.

The campaign that the Department of Health is engaged in is for pure air inside the home, inside the confines of our living places, and for a pure general air supply. A pure outside air is not the most important part of the pure air campaign. The greatest part of the harm that is done by bad air is done by bad air within enclosures, especially in assembling places, but of greater consequence is the harm that is done by working in places in which there is a large amount of inorganic dust.

Whereas there is a difference in the tuberculosis rate among people who live in good homes compared with people who live in bad homes, that difference is not nearly so great as the difference between the tuberculosis rate of those who work in good places as compared with those who work in bad places. For instance, bankers have a death rate from tuberculosis of 95 per 100,000, as compared with 495 for stone masons and those who work in an atmosphere containing a large amount of inorganic dust, especially sharp-edged and sharp-pointed dust; nevertheless, of great importance is the purity of the general air supply.

Now, coal smoke has a relatively small amount of carbon monoxide, which is a most noxious poison, but at the same time it is probable, by reason of the very rapid diffusion of gases in the outside atmosphere, that this carbon monoxide rarely, if ever, reaches men in sufficient quantities or in sufficient doses to be of harm. I speak now of the unconfined air. Carbon dioxide does relatively little harm for the same general reason; that is, by reason of the rapid diffusion of this gas in the outside air, and also by reason of its very low capacity for harm.

In this country, up to the present time, our efforts at smoke suppression have been directed almost exclusively at dense smoke, which means that our campaign has been against unconsumed carbon and has not been against the gases of smoke or the volatile substances and the sulphur compounds. These are much more harmful than the suspended carbon, and we are beginning to receive complaints on that account. For instance, we will say that on Madison Street there is a building sixteen stories in height, and that immediately across the street from it is another building ten stories in height. The tenants or the

owners of the tall building come to me saying that the building across the street (I mean now the operators of the lower building) are running a smoke preventive installation that does not give dense smoke, and in consequence it conforms to the existing law, but that these objectionable gases are being wafted into the windows of the tall building, making conditions thoroughly objectionable.

As Mr. Bird, year by year, gets more density or carbon out of the smoke, he will find that it will be necessary to have the smoke ordinances redrawn so that they shall comprehend some other products of combustion than carbon. It stands to reason that the method of treatment of these points must be divergently different. Our effort to prevent the lifting of unconsumed carbon must be in the direction of better consumption of the carbon, but of course that is not true of these volatile products, including the sulphur compounds. In London the campaign within recent years has not been against the general smoke, but against the other noxious products of coal combustion.

There has been some confusion in the public mind between the effects of smoke and the effects on the health of those who mine coal, and who work in an atmosphere with much coal dust in suspension. Generally they are brought but slightly in contact with the products of coal combustion. Coal miners are generally residents of the country, or residents of a type of country in which there is much of the open, or in which there are not usually crowded habitations. I have not yet determined, however, as to the amount or prevalence of lung disease that is to be found among the workers in coal mines. I have only this to say in that connection, that here are two questions quite apart and having relatively little to do with each other; one has but little bearing on the conclusions that are to be drawn from the other.

I have mentioned that in this city we have spent some \$50,000,000 in order to reduce our death rate from typhoid fever. The number of people who died in Chicago last year from typhoid fever was 338, and the number that will probably die in Chicago from typhoid fever this year will be well under 300, as I now estimate it. This will be not only the lowest typhoid death rate that Chicago has ever had, but will also be the lowest typhoid death rate that any large city in America has ever had. With 300 deaths from typhoid fever, how does this compare with bad air diseases? Last year we had practically ten thousand deaths in Chicago from bad air diseases, or one-third of the total death rate of this city was due to the group of diseases that are attributed, in a major part, to the pollution of the air. Now, if it was worth while spending \$50,000,000 of the public money to get rid of this little bit of typhoid fever, is it not much more worth while to spend some money to get rid of consumption, pneumonia, bronchitis, and influenza, that together are

not only the largest source of death in our community, but that do more to make for poverty than every other influence in the community combined?

We have heard the statement made that smoky cities are cities in which there is a large tuberculosis rate. We have also heard that the mining districts are districts in which the tuberculosis rate is low. In the investigation of the accuracy of these statements, we have gone simply far enough to compare the returns as they are in from Pittsburg with the returns as they are in from Chicago, with a view of discovering if there is anything in these records to sustain those statements.

[Dr. Evans here presented a comparison based on reports of the Board of Health of Pittsburg and Chicago as to mortality from bad air diseases,—that is, tuberculosis, pneumonia, etc., which were classed together,—and the result of comparison of the summaries is as follows:

1901 mortality per 100,000,	Pittsburg 521;	Chicago 441.
1905 under the same conditions,	" 524;	" 413.
1906 .....	" 486;	" 424.
1907 .....	" 604;	" 528.]

From this tabulation, the figures of which are taken from the recognized authorities (the United States Census Bureau), it would seem that the deaths from impure air diseases in Pittsburg are persistently higher from year to year than in the city of Chicago. During the year 1908 they exceeded the Chicago deaths at the rate of 144 for each 100,000 of population. The excess for these bad air diseases in percentages, expressed in percentage of Pittsburg over Chicago, was 21.2%.

I do not know what the figures will show when we have made studies of the comparative maladies of mining districts and of districts in which coal is consumed in large quantities. I do not know what the figures will determine, as to the harmfulness of coal dust as distinguished from the harmfulness of coal soot, but I can say that as far as these investigations have gone, they confirm the common sense proposition that dirt in the air does not make for health; that dirt in the air does not make for the well being of human beings any more than dirt in milk, or dirt in water, or dirt anywhere else.

*President Allen:* We thank Dr. Evans very much indeed for his talk this evening. It is not often that we engineers have the privilege of going outside of our trade, as we have had the opportunity of doing this evening. We want to get at this smoke consuming proposition in a large way. We have tried to treat it from all sides, and I am sure that we will carry away these addresses and this most valuable information, and that they will be of help to us as engineers, as individuals, and as citizens.

*Mr. Joseph Harrington, M. W. S. E.:* The question that is the

most important here tonight is the conclusion which I draw from the various remarks. The attack on the Smoke Department by some of the newspapers have been referred to. It seems almost obvious, after hearing the discussion this evening, that anyone who would say publicly that the way to stop smoke in the city of Chicago is to assess a lot of fines, is absolutely wrong. Nobody knows any better than I do the practical difficulties of the problem. There are absolutely no two installations which offer the same conditions; they cannot be treated alike, they must be treated on their individual merits, with the application of common sense. If the Smoke Department were compelled to fine everybody who makes smoke, the thing would fall of its own weight.

One of the rules of our office, which is rigidly adhered to is, that if anybody has a criticism to make of anything or of any person or of any method, he must be prepared to offer a solution. In other words, we do not want mere complaints, we want a constructive policy. Now, the Smoke Department in Chicago offers that to the smoke producers, and they have a policy to solve in a great measure the problems which are presented to them. The application of personal judgment is absolutely essential in that Department. In many cases a fine will not accomplish the desired result. The public must be educated. The smoke proposition is necessarily a campaign of education, and if you had occasion to investigate the great variety of conditions that Mr. Bird has presented to him, and which I personally know about, you would appreciate that nobody can stop smoke in the city of Chicago by going around like a bull in a china shop, putting fines on everybody who makes any smoke. It cannot be done in that way, and I think that it is up to the engineers of Chicago, and especially of this society,—who by their natural training have the ability to appreciate these facts,—to support the Smoke Department in some practical way. It is up to us as engineers and as understanding this proposition, to place it in the right way before everyone interested, and not to condemn the Smoke Department for not fining everybody in sight.

*Mr. C. F. Heal* (of Borland Bldg.): We have been told about the backing our Smoke Department has, and we all thank Mr. Bird for his paper, but our difficulties are not fully understood. For instance, I am operating a plant and hire a man as fireman. He is given full instructions as to what he is to do, but the first thing I know he neglects his fire for a minute or two, and then I get a smoke notice. We go out in the street and see our stacks smoking, and immediately go back to the fireman, but that does not prevent our being called to account. I must say, however, that when I have been before Mr. Bird I have been treated very fairly, and will endorse what has been said about his use of discretion.

*Mr. Alfred Johnson* (Mandel Brothers): The time is short but I do want to say that if the program we have heard is being followed, and the Department is given the authority that it should have, and it uses discretion, it will continue to have the solid support of the operating engineers. I do not believe there is a body of men in Chicago who have been as loyal in their support of the Smoke Department as the operating engineers, and I do not believe there is a body of men who have spent the amount of time and energy and study of means to prevent smoke in the city of Chicago that the operating men have. A discussion of this kind brings us together and does much good, and we ought to have more of it. We also should have some scientific discussion on the elimination of smoke.

I am one of those who have been censured for creating smoke, and I do not feel at all ill-willed towards Mr. Bird. He has done everything possible to aid us, has consulted with us, has had his men in our plant, and we have done everything we could. We have spent a great deal of money and are willing to spend more, but we do not want to spend it unwisely. If something could be developed so that by spending \$50,000 we could eliminate the smoke, we would not hesitate to make that expenditure, but we do want, and insist on having a perfect understanding and a harmonious feeling between the Smoke Department and ourselves. I am glad to hear what Mr. Donnelley had to say, and to know that discretion will be used.

#### DISCUSSION.

*Adjourned Meeting, Nov. 26, 1909.*

*President Allen:* A week ago last Wednesday we listened to a paper from Mr. Bird on Chicago's Smoke Problem. The discussion was very full, and we found that we did not have time enough to listen to all the gentlemen who were prepared to speak. It appeared that the smoke problem was an extremely live one, and in order to cover the ground satisfactorily, to hear from those whom we wanted to hear from, and to learn all we could about it, we decided to call an adjourned meeting. I am glad to see that our expectations have been realized, in the large attendance this evening. Inasmuch as we had such a hard time getting through at the last meeting, we will start right in, and I want to call upon Mr. Bird to open the discussion.

*Mr. Bird:* I believe that I am not expected to talk much tonight, but to give all the time possible for others. Of course it is very gratifying to me to see such a large attendance tonight, but I know that the interest is in the general subject of smoke prevention, rather than in the particular subject matter that was in the paper that I read last week. I hope that the discussion may be very general and frank, and I am quite sure that if, at the end of the evening, we are not all talked out, the society will be good enough to let us have even a third meeting.

June, 1910

*President Allen:* I would like to state, before beginning the further discussion, that Mr. Bird and Mr. Kuss are here to answer any questions that may be asked, and in order to save interruption, I will ask them to make note, so far as is possible, of such questions, and answer them at the end of the meeting, at which time an opportunity for so doing will be presented.

The operating engineers had very little chance at the last meeting. The meeting was taken charge of almost entirely by the smoke prevention people—not the people that make smoke—and so this evening we want to give the operating engineers the very fullest opportunity. I will first call on Mr. Naylor.

*Mr. C. W. Naylor, M. W. S. E. (of Marshall Field & Co.):* I will state, for the benefit of my many friends and acquaintances here, that being a member of the society and not knowing after the last meeting that there was to be an adjourned meeting, I sent in my discussion, as is the custom with members of the society, expecting it to go into the proceedings. In view of the fact that there are so many here tonight who are prepared to talk, I will not address you at random; I will not even enlarge on my own views, but will simply read them to you and leave the discussion for those who came here for that purpose.

The rules regarding supervision claimed to be new by this department are not new but have been borrowed from the department's predecessor.

Intelligent supervision of installations did not originate with the present bureau. The majority of all non-smoke plants now in Chicago were installed long before the present bureau was appointed,—in most cases without any help from the smoke department.

The present department admits having made some mistakes. They say confession is good for the soul. This department, like all preceding ones, had to learn how to prevent smoke before undertaking its suppression, and it has probably accomplished more than any previous department. The statement that "Next year we are going to do things to the tugboats," has been heard before. It is a perennial and hoary chestnut with the smoke department. It has been a regular November and December stunt of all preceding smoke boards, and yet each spring we will find the same old smoke belching from the stacks of most river craft.

Mr. Bird's anxiety for the consulting engineers and their cry for bread and butter was very pathetic, but misplaced. There are remarkably few consulting engineers in Chicago who know even the rudiments of smoke burning.

The Milwaukee smoke inspector who could not see smoke on his trip about Chicago, was not on to his job. He can be shown smoke pouring from at least twenty-five schoolhouse and waterworks chimneys during a two hour ride on our elevated

railroad system on any cold morning. All these schools are under direct control of a city which is trying to make its citizens stop smoking with their private chimneys.

The Smoke Department must devise some method of notifying offenders *at the time* they are violating the city ordinance, and not twenty-four hours later by mail.

The department must compel the installation of an automatic smoke recording device, either as a temporary installation for the purpose of instruction, or better, as a permanent improvement.

The elimination of color from smoke—in other words, the prohibition of *black* smoke—will not cure the worst evils of smoke, although it may increase our daylight. Large center chimneys on each block, at least 400 feet in height, will diffuse the gaseous poisons above the heads of the air-breathing public.

The Smoke Department, to be a respected and honest organization, must stop smoke from all city chimneys, whether in schoolhouses, office buildings, city halls, waterworks, fire engines, machine shops, or electric light plants, before it presumes to tell the citizen not to smoke. Plant owners should not be fined, on the unsupported evidence of one inspector, but better proof should be required to make a case.

*Mr. A. L. Hadin* (of the South Side Elevated Railway): I do not know why I should be the second man called on, as speaking is not my custom. I believe, however, in regard to the Smoke Department and the smoky chimneys of the city of Chicago, that there are smoky chimneys and there are not smoky chimneys, and those that are not smoky have been made so largely through the aid of the Smoke Department, as well as by those in charge of the plant. The consulting engineers, in my opinion, have very little to do with preventing smoke. They sit in an office and, like a good many doctors, have a shingle out and look wise, but it remains for the fellow who handles the fire to prevent the chimney from issuing a volume of smoke. The statement was made at the last meeting that plants can be equipped to prevent smoke under certain conditions, but those conditions probably do not exist in 90% of the plants throughout the city for fifteen minutes at any one time.

Now, who can build a furnace that will prevent smoke under all conditions? The only way smoke can be prevented is by carefully watching the handling of the plant and the furnace. It seems to me that in all this talk about smoky chimneys, sufficient thought is not being given to the unfortunate fellows who have to stay down in basements, which, in a good many cases, are not fit to stay in, but for which some consulting engineer has designed a boiler plant. Neither Dr. Evans nor the consulting engineer has made any provision for these men, and they are the ones who are going to get the blame for every

dirty cinder and all the smoke. I believe that a furnace can be built and installed that will not make smoke under certain conditions, but that those conditions are rare.

In a majority of the plants where there is only one boiler, something may happen to that plant,—an arch may fall down or a tube may break; in fact, there are one hundred and one things that occur in a boiler room that cannot be prevented. Now, an inspector from the Smoke Department may see a chimney smoking, caused by such conditions, and will report the matter; then a notice from the Smoke Department will be sent. I believe that some concession should be made in such cases, and that violators should be notified at the time the smoking occurs, so that those who are making the smoke may see for themselves.

*Mr. J. H. Morrow* (of the Great Northern Hotel): I was present at the meeting last week and, like many others, realize the opportunity that has presented itself to our City Smoke Department to follow this question in a more vigorous way than they have in the past. Mr. Donnelley, the President of the Smoke Commission, outlined the policies that they intend to follow in the future. I fully appreciate the position in which the Mayor was placed when he appointed this Commission. I believe it was a fortunate thing for the Mayor, because it shifted the responsibility to other parties, and more particularly to business men who have to cope with this proposition. At the same time I realize, and I think my fellow engineers will agree with me when I say that the conditions that exist in boiler rooms are not altogether ideal.

The operators of furnaces have been endeavoring to co-operate with the Smoke Department, to prevent the nuisance that our Health Commissioner, Dr. Evans, claims is so injurious to the general public, and I think the engineers of this city have given their co-operation, almost to a man, to prevent it. Mr. Bird, the chief smoke inspector, I think, realizes that the engineers are endeavoring to work with him.

We have a great many kinds of coal to contend with, and we all know that when our plant is designed to perform a certain duty, whether the boiler is underloaded or overloaded, there is a point in every boiler plant that is economical. For instance, when we start up a cold boiler we are going to make smoke, because we must obtain temperature before we can consume the carbon and prevent the making of smoke. Also, if we overload our boiler plant we are going to make smoke. Now, those are the conditions with which the operating engineers of this city are confronted, and I do not believe that these conditions are entirely taken into account by our present Smoke Department. If some kind of a system of notifying the operating men could be devised at the time the plants were smoking, I

think that we could work together in a manner more nearly harmonious.

I think that at the time the Commission was appointed to co-operate with the Smoke Department, that a Commission should have been appointed to sample the coals that come into this market, and that are delivered to buildings after they come into this market. It is a fact that where you expect to get certain grades of coal, in certain instances you get a bad load of coal, or a number of them in your plant, and you are going to make smoke. The plant must be kept going at any cost; that is the first requisite of any good engineer. So the Smoke Department and the business men of this city should realize, if they have not already done so, that the coal market of Chicago should be taken into account, in the plans for prevention of smoke. If we can get a high grade of coal—one that comes up to the standard—and the coal companies are not allowed to send coal that is under grade into our boiler rooms, this will go a long way towards the solution of the problem and will greatly assist the engineers in co-operating with the Smoke Department. We would not be here tonight if it were not for the fact that we want to co-operate with that Department and prevent smoke to the utmost of our ability.

*Mr. Alfred Johnson* (of Mandel Brothers): This subject is one in which we are vitally interested. There are without doubt many smoky chimneys in Chicago, but there are not nearly so many as there used to be. I believe that fully 90% of the smoke in the downtown district has been eliminated within the last two or three years. It used to be a rare thing to look up and not see many smoky chimneys. Now, you can go along the street and look up, and while you find some smoky chimneys, still you do not find them to the extent that you did formerly.

Smoke prevention is a hard problem. There are times when we will make smoke, when we are doing our utmost to stop it. The matter has bothered us a great deal. I have at times gone out on the street or up on the roof of our building and found our chimney smoking. I would then telephone to the engineer and ask him what he was doing. He would make an examination and reply that everything was as usual, and he could see nothing wrong. I have then gone downstairs immediately, and in looking through the boiler room have found that he was apparently telling the truth. Possibly a little closer inspection would have revealed a hole in the fire somewhere, but that is hard to see.

There are other times when we know we are making smoke and that we shall have to continue doing so for some little time. We had a case a week ago when a flue blew out and a lot of water drenched the fire. I knew we were making smoke, but fortunately for us the Smoke Department did not discover it. The water put the fire out so fast, however, that probably the

smoke did not last for six minutes. It happened to be a bright day, and we were able to get along with the rest of the boilers without serious inconvenience until we got another one ready. If it had been a dark day when we would have had to carry a maximum load, I know we would have had to smoke for over an hour.

It is with things of this kind that I want the Smoke Department to be given the power of discretion to forget and forgive. I think they ought to be endowed with that power, and I believe Mr. Donnelley intimated as much. I thoroughly believe it is unfair to be fined for something one cannot prevent, when he did his best to do so.

Another thing I fully believe in, is that the Smoke Department should more than ever co-operate and advise with the engineer and I do not think that the Department ought to be curtailed. It has offered advice freely, and has done much to help the engineers, and I think this service should be extended instead of being cut off. If the Department has not the proper amount of help, it should ask for a larger appropriation and have more prominent and practical engineers to advise with the operating engineers.

I do not think there is any need of advocating, or in fact, asking the consulting engineers to go into the work, because I have not found any of them who knew any more about it than the operating engineers. They may tell you to try this and try that and maybe you will succeed, and maybe not.

There is no absolute cure for any smoke problem. Each individual case must be considered by itself. The Department at present sends one inspector who advises; this is a good practice, but I think two men should be sent to go over the matter thoroughly, be sure of their ground, and then advise. If the advice is followed without success then the engineer should be exempt from censure until something else is tried.

It has been very discouraging to many of the engineers who have been able to run their plants for a time practically without smoke, to have failures occasionally. The average plant down town is fairly smokeless, and I do not think any of them that are well equipped and taken care of smoke one-eighth of the time as the law allows. Anyone may smoke six minutes in every hour, but if he makes no smoke for a whole day, and then the next day smokes six and a half minutes in one hour, lo and behold he gets the axe. It does not hurt the operators' feelings nearly so much as it does those of the owner of the plant. The engineers become case-hardened, and say: "Well, we did the best we could; of course, if smoke escaped, we regret it, but must grin and bear it." We all know, however, that if we continue to make smoke our employers get very much wrought up about it. It is not so much the fine that they have to pay,—

because they have spent probably ten times that amount, or a hundred times as much, trying to put in a device that would prevent the smoke,—but it is the fact that they are brought up in court and sued that hurts them.

I think the ordinance ought to be changed so as to allow the Smoke Department to use discretion, in case it finds that the plant is being operated to the best advantage under existing conditions. Where the owner is willing to do anything and everything that the science of smoke prevention has decided should be done, he ought to be given the same privilege as the railroads are given.

*Mr. John F. McGrath* (of the Hartford Building): I came here, although I am an old fellow, on the theory that it is never too late to learn. I did not come to talk. I will say, however, that when an old friend is about to pass away, a man is indeed an ingrate if he has not a good word to say for him, and consequently I say that smoke is Chicago's best friend.

The tale of suppression of smoke in Chicago really began with the tail of a shirt. I was in the Council Chamber something over 36 years ago, on the 10th of November, 1873, when a petition was presented asking the Council to compel the North Chicago Rolling Mill to burn its smoke. That petition was signed mostly by residents in the neighborhood of Union Park, which was the first pretentious park that was finished in Chicago, and at that time they thought it was going to be the principal residence district of the West Side. To show that it was not brought in under any particular proposition, it was referred to the committee on fire and water. The claim made was that when the wash was hung out on the clothes-line (and in those days we never dreamed of such a thing as the steam laundry jumping up to be a thorn in the side of the Chicago Smoke Department) the smoke from the Rolling Mill, three miles away, got to the shirt before the sun did, consequently they could not vie in the purity of their linen with their brothers of the South Side.

The Mill at that time was a very large institution, probably the largest industry in Chicago, working 24 hours a day, making iron rails, and it sent up a pall of very thick smoke for about two or three miles around. Now, I might not be able to argue with my learned friend, Dr. Evans, who spoke here for the Board of Health, but I will take the lawyer's argument and prove an alibi. That Mill at the time had between two and three thousand of the most robust, healthy men I had ever seen. They made plenty of money, worked plenty, ate plenty, and I would be the last to claim they did not drink plenty. The agitation caused a good deal of discussion and argument, as well as some little annoyance to the parties interested, and it was claimed that such a thing as burning the smoke was out of the

question. If they had shut down that plant it might have resulted in shutting down Chicago, so they simply wound up by consigning the signers of that petition to the place where all authorities agree there is a great deal of fire, and where I think theological history would say there is some smoke. This kept on for a couple of years. There was not much done, but two or three years afterwards, at every meeting of the Council there was a mass of from ten to a dozen petitions from men and firms, asking permission and guaranteeing absolutely to do away with the smoke nuisance at a percentage of saving—well, you might write in your own percentage, they left it blank. And so the agitation was kept up, through the newspapers and otherwise. I remember that a committee was formed, and after they had gone out and made a public inspection of Bill Jones' patent smoke burner, they described the great invention and showed where Jones had discovered that steam at a temperature of 327 degrees would consume all smoke, adding that any engineer and fireman who continued to make smoke after that demonstration ought to be in jail.

I will never forget one day meeting the late lamented Joseph Medill chief editor of the *Tribune*; he had been down looking at a demonstration of Smith's patent burner. (There were seven Smiths here at the time, and this one was a man they called Crazy Smith.) He began explaining to me the amount of money Chicago property owners would save in the first cost on a practical smoke consumer of that kind. The smoke-stack would be done away with altogether, and all that was needed was a little piece of pipe. It was a "simple" invention; a large steam jet in the breeching of the boiler forced the gas under the fire, so it went like a merry-go-round, from one to the other. Very few of us tried it; so we kept on until after the smoke ordinance had been passed, and then the operating engineers were up against the proposition; smoke had to be done away with, and they commenced to get busy.

Along in the 80's, nearly every second or third man running a plant had a patent smoke burner. We cut down capacity, and we finally did away with a great deal of the black smoke. Along in the early 90's there was a great wave of reform, a Commission was appointed, well-meaning men put in their money, and the city was going to do away with smoke once and for all. That was the first time in the history of Chicago that we could have gotten a practical method of doing away with smoke, yet that Commission I claim was the biggest fizzle we ever had and set back the suppression of smoke for many years. The first move they made was to hire a lawyer. Then they met and mixed up a prescription and sent it around to all the operating engineers. I think it was to be taken three times a day, before firing, and, like the small-pox, if it did not "take" in

ten days, the lawyer got the case. Well, it only took in about one-half of one per cent of the cases, and the lawyer was kept so busy that he ate up all the funds, and then the whole thing went up in smoke.

About that time the skyscraper was inaugurated. The people of Chicago had gotten to a period where they could do things which they could not have done when the subject was first brought up. Thirty years ago it could not have been done, and if an attempt had been made there would have been nothing here today of which to make a city beautiful; but at this later time I claim it could have been done, and, through a practical rule and practical supervision, an immense amount of good could have been accomplished.

So we kept along until a few years ago when the next Smoke Commission was appointed, and now we have supervision of the installation of the new plants. The younger men may say, "Well, you old fellows did not know anything." I contend that this is not the case. An architect designs a building, and it is left for the operating engineer to solve the problem of how to burn the smoke. Now, at least, if the plans are not properly made, the Department sees that you have room in which to work out your salvation. In that respect I claim the present Smoke Department is the best we have ever had, and it is on the right road to success.

As to the workings of the present ordinance, I must say that the Smoke Department has done a good deal of good in the way its representatives have gone around among the plants giving advice in regard to the installation of new plants and the reorganization of old ones. Of course, they have brought suits, and I would not like to be guilty of a breach of courtesy to this Society and use the language I would like to in regard to some of the inspectors, because, like many others, I have had my day in court. I have paid the bills, however, and it is seldom that a man is brought in under the smoke ordinance that he is not proven guilty,—at least practically guilty. He might have lots of extenuating circumstances, but he could not prove an alibi.

The only time I was ever sorry for pleading guilty was years ago before a Justice of the Peace. The case had been postponed several times, and when finally called for trial I said, "Why, yes, I am guilty." The judge wanted to know how bad I was guilty, and asked the inspector to read the charge, but the inspector had forgotten his book. The judge then said: "The best thing you can do is to go and pay the costs and go home and behave yourself."

The first man I ever worked for when I came to Chicago was Gurdon S. Hubbard, and I have often heard him tell the story of how he once paid the entire taxes of this city. That

was years ago when this part of the state was in Vermillion County, with the county seat in Danville. He said there were a couple of small tribes of Indians that got very playful and frisky around here, and sooner than come up from Danville, he put his hand in his pocket and paid the entire tax of the city of Chicago, which was \$2.30. And this man's widow is right here in our midst today, a good, healthy woman yet. Is there any other city in the world where a woman can get up and say: "Well, my husband paid the entire tax of that city, only about half a day's pay." Then think of our millions of people and our hundreds of millions of dollars invested! Mrs. Hubbard does not attend the meetings of the Ladies' Auxiliary, neither does my old friend, Mrs. Clybourn. They both came here a long time ago, and say that when they got here the only way they knew that this was a city was because they could see smoke. The only thing that gave Mrs. Clybourn any encouragement at all was a little bit of smoke that went up. That was the only beauty about the town when she got here, and she does not attend any anti-smoke meetings. She says that smoke built the town and she doesn't see why there should be any objection to it. She is still here, hale and hearty.

You must consider that this is a wonderful city. You younger men do not realize how quickly it has grown up, and when you think of all that has been done in the suppression of smoke in the last two decades, isn't it really a libel on the young men to say they cannot find a way out of the difficulty? I think it is nonsense. They will accomplish results, and they will do so without causing the big corporations any great hardships. It has been done with the stationary plants, and surely the generation which is coming can solve this problem, which does not present nearly the same difficulty it did to us.

Now, gentlemen, when you see a little smoke coming out of a chimney where a man has just put a fire under his boiler, don't ring up the Smoke Department. It will not last long, and it will not kill you. Something more than two weeks ago I was up on the roof of my building one morning about eleven o'clock, with a friend; the wind was blowing from the north-east, and the horizon was as clear as crystal. Without fear of contradiction I will say, that from Twelfth Street on the south to Grosse Point on the north, taking in all the old North Side section, there was not one violation of the smoke ordinance.

Now, gentlemen, when you consider the hundreds of thousands of tons of Illinois coal that is burned without smoke, I think that the men who do it ought to have your support, and when the men who are responsible for the dirt and filth and ragged condition of our streets have done as much for improvement in that direction as the engineers have done in theirs, it will be time for us to compare notes.

*President Allen:* It is extremely interesting for us to hear of the smoke problem in a chronological way, as Mr. McGrath has brought it out, and to know the panaceas that were offered and the way that they have followed each other into the dust heap. That is the same story over again, that it is not so bad to be ignorant as it is to "know so much that aint so." We all know of so many things that have been proposed as absolute remedies for smoke, but they haven't always "proved up."

*Mr. Frank Elliott* (of the Northwestern Elevated R. R.): I thought until about a month ago that I had done a good deal towards preventing smoke on my side of the town, but I had my wings trimmed by the Smoke Department. At first I offered various excuses which I thought were very good, but they were not accepted, and I found that the only thing to do was to stop making smoke, regardless of expense.

If one of our men got sick, and we did not have a man to put in his place at the fires, we were told that we must keep men on the ground who could take care of the fires, and I decided that I was going to keep men enough on hand to do the work as long as I was permitted to do this. So I went ahead and tried to do what I could. I think we have accomplished much, but I know that we make some smoke.

I have seen a great deal of smoke in Chicago, but this has been very much modified in the last ten years. I have made more smoke this summer, I will admit, than I made in the previous nine years, but I am doing a good deal more work, and the times are so good that the men leave and I have to hire a few new men to keep things running, but I cannot always keep the same set.

With plenty of draught, I think any good type of furnace, carefully handled, will practically eliminate smoke. But I think that there should be a little immunity extended to men who do not make smoke more than half an hour out of the twenty-four. I believe there is a reasonable excuse for some men making smoke occasionally.

*Mr. A. J. Saxe*, M. W. S. E. (of the Corn Exchange National Bank): I can myself remember some of the days Mr. McGrath describes; they are very interesting; but what we wish to know is how to suppress smoke.

Last week Prof. Goss recommended that we pool all our plants into one big plant, and furnish power from one point. There could not be enough of these large plants to run Chicago anyway, as there will always be more or less small plants, and they will have to be properly taken care of to do proper work.

I remember one day in 1879, when my brother and I were walking down Adams Street, that as we passed a building where the Marquette Building now stands, there was a big brass plate on the front which said: "Hutchinson's smoke

burner for locomotives and stationary boilers." I said to my brother: "What is that?" and he replied that it was a method of burning smoke. As I never had heard of such a thing, we investigated and found that it was a casting which went in the furnace and blew steam over the fire.

There is one thing in our present ordinance that I do not think is right, and I think it should be changed. That is the six minute allowance for smoke. There are some people who make four and a half, five, and five and a half minutes of smoke every hour. We never go out but we see their stacks smoking. They make smoke on an average of one hour out of twelve every

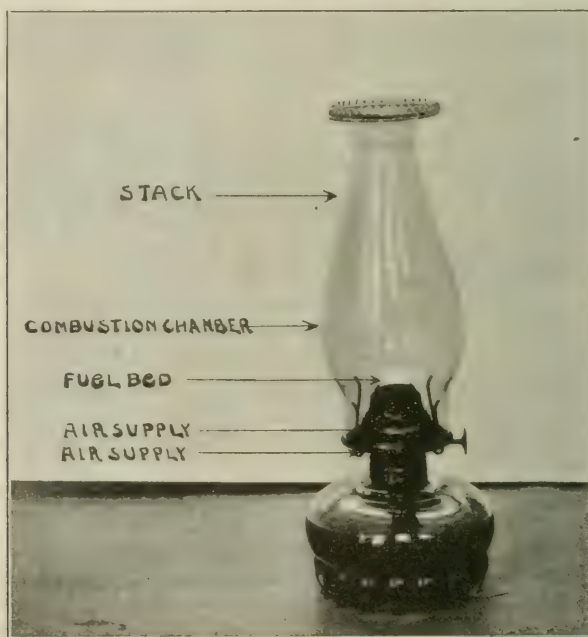


Fig. 1.—Kerosene Lamp to Illustrate Furnace Performance.

day, and they never get a notice, neither are they fined. I am on the road to a lawsuit myself. We think we have a pretty good chimney. We generally fire up our green boilers at night, but on the 3rd of October, when I came down in the morning, we found a leaky tube cap and had to shut down, draw the water and take out the fire. I told the engineer to let the boiler go until night before he fired it up, but this occurred on a cloudy afternoon; the load got heavy, and he had to start it up, and in firing he made eight or ten minutes of smoke, and we got a notice from the Department. Of course, that was no more than right, we had violated the ordinance and were entitled to the

notice. From that day we did not make any smoke until the 23rd. On that day we were putting in new catches on the stokers, and in changing over from one to the other there was about half an hour when the men shut the stokers down and fired by hand. During that time they made smoke from eight to ten minutes, and we got another notice, and this time we



Fig. 2.—Lamp Burning with Clear Flame and Open Hood.

were notified that we were sued. Now, we made twenty minutes smoke, I guess, in four months. The other plants make an hour's smoke every day and yet do not violate the ordinance. I think the man who makes the most smoke in a week or a month should be sued, and not the man who makes ten minutes smoke once in two or three months.

To illustrate my remarks, I will make a few experiments, using an ordinary kerosene lamp, the best example of a theoretical furnace that can be bought in the open market today. It is probable that the different oil companies have spent more money in perfecting the kerosene lamp than has been spent by all the furnace companies combined in furnace improvement. The result is an almost perfect device. On inspecting the lamp, we find that it embodies the principles required in a well designed furnace for burning coal; the only bad feature is that its air supply is cold. More economical results would be obtained if the air was hot, but in a lamp this is almost an impossibility.

By taking off the chimney and opening up the hood, we find that the wick can be raised or lowered to increase and decrease the amount of light required. This feature corresponds to the conditions of fuel in the furnace or the coal on the grate. The perforations around the wick and underneath the hood represent the openings in the grate of an ordinary furnace. The holes



Fig. 3.—Lamp with Closed Hood and Without Chimney, Producing Smoke.

around the outside of the hood, which are inside of the chimney, are to let the proper amount of air over the flame or fire, the same as is required in a well designed furnace. The bulge in the lamp chimney represents the combustion chamber, and the chimney above this bulge represents the furnace stack. The height and area of this stack has a great influence on the strength of draft. The duty of the chimney stack is to supply

air to the furnace and discharge the hot gases to the atmosphere.

Air is composed of 21% oxygen and 79% nitrogen, but the oxygen is the only part which causes combustion; nitrogen is taken into the furnace only to be heated at the expense of the fuel, and it passes up the chimney and produces no result except to assist the draft. It is necessary, however, to pass this amount of inert gas through the furnace to get the proper amount of oxygen, the same as it is necessary to put an amount of earth



Fig. 4.—Same Size of Flame as in Two Preceding Views, with Chimney on Lamp.

matter into the furnace with the combustibile. It requires 13.6 cubic feet of air to weigh one pound, and theoretically it takes about twelve pounds of air to burn one pound of coal. In best actual practice, from 18 to 20 pounds of air is used per pound of coal. If we consider how much air is required to burn a ton of coal, one may be surprised. 13.6 times 20 equals 272 cubic feet of air per pound. This multiplied by 2000 (the number of pounds in a ton), gives 544,000 cubic feet of air required to burn one

ton of coal. This is more air than is contained in any of our fire rooms, and the question is, where is this large amount of air coming from? If provision is not made for it to enter the boiler room, satisfactory results can not be obtained. I will illustrate later with the kerosene lamp some of these conditions.

By removing the chimney, opening the hood, and lighting the wick, the resulting flame appears like that of a torch burning red at a very low temperature and it smokes badly. This smoke I will reduce by turning down the wick so that the fuel supply balances the amount of air surrounding the flame. We now close the hood and the flame again begins to smoke. This shows



Fig. 5.—Large Clear Flame, Due to Draft Produced by Chimney.

that the hood cuts off the mass of air surrounding the flame. This is analogous to a furnace running with a very poor draft; with such condition the fuel supply on the grate is usually too large for the amount of air admitted to the furnace, so that proper combustion is not secured. We now place the chimney of the lamp in position over the burner with the result that the smoke at once ceases; the flame brightens up and the temperature increases, showing better combustion and more economical consumption of fuel.

If the furnace is a hard-fired one, with a poor draft, the fireman should manipulate it as follows: Open the fire door on one side only; place about two shovels of coal on the grate; close the door; wait for an interval of two or three minutes; then open the door on the other side of the furnace and put two or three shovels of coal on that side. This method will keep one side of the furnace burning hot and thus consume the gases on the other side, which the fresh coal is throwing off.

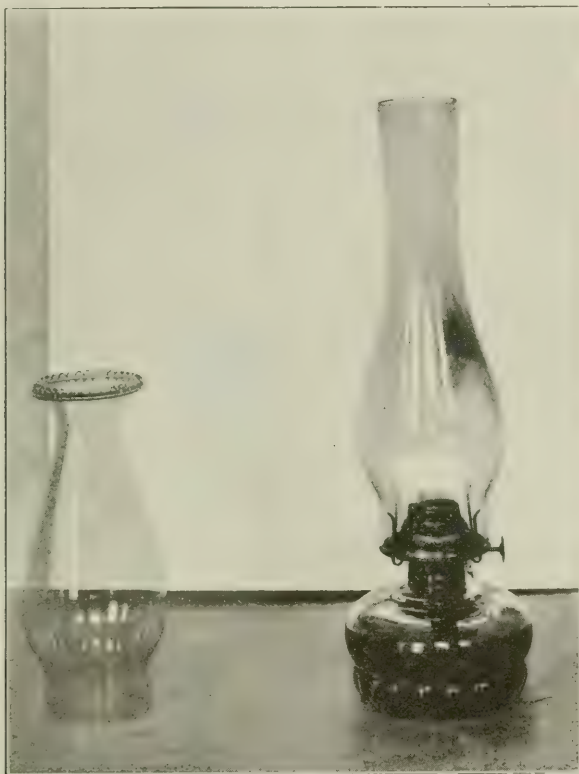


Fig. 6.—Still Larger Clear Flame, Due to Draft from Higher Chimney.

Unfortunately but few firemen employ this method. They usually prefer to load the furnace with a large amount of coal, producing a condition illustrated by turning up the wick of the lamp, which makes it smoke badly. As the fire in the furnace burns down, as represented by turning down the wick, it reaches a point where it does not produce smoke. Then by turning down the wick still lower, we get a condition which represents a fire burning too low for economy,—too thin and too much

cold air going through it,—and which dilutes the gases and chills the furnace. Following the usual furnace performance from this point, the steam pressure then begins to drop and the fireman thinks it is about time to load up the furnace again. This operation is repeated time after time, a large amount of



Fig. 7.—Very Large Clear Flame, Due to Extra High Chimney.

smoke being made each time, while if the firing was light and often and the fire was kept thin, with the dampers open, much better results would be obtained both in economy of fuel and

smokeless combustion. We might consider in this case that the draft at the fire would be equal to 0.1 in.

I will now change the chimney on the lamp. The one I am taking off is about 8 in. high, and the one I am putting on

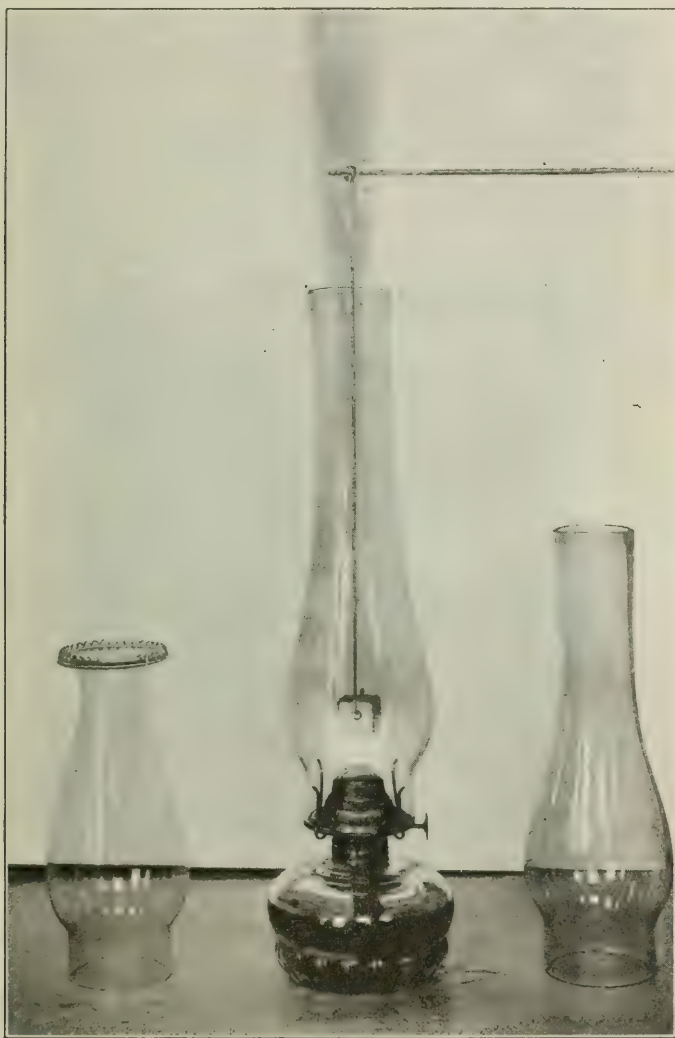


Fig. 8.—Smoke and Incomplete Combustion Caused by Chilling of the Flame.

is about 10 in. high. You will notice at once a decided change in the action, as the wick now may be much higher, producing a whiter and better light and more of it without making smoke.

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This may be considered as analogous to running a furnace with about 0.2 in. draft. Under this condition more air is brought through the furnace, more coal can be burned per square foot of grate, and more horse power can be developed in the boiler, with greater freedom from smoke.

If we desire more power from a boiler we put a larger fire under it and evaporate more water in the same interval of time. So, to illustrate, I will turn the wick still higher until the lamp

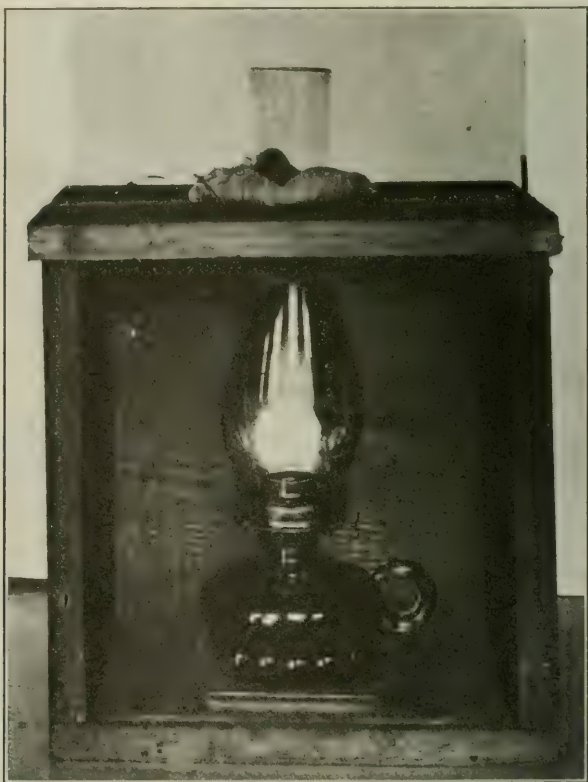


Fig. 9.—Lamp in Box Burning with Large Clear Flame, the Glass Front Open, Affording an Unobstructed Air Supply.

with its 10 in. chimney again begins to smoke. Now we will remove the 10 in. chimney and put on one 14 in. in height. The smoke again ceases and the flame is larger and brighter than before, showing that more air is brought through the furnace, the combustion is more rapid, and better results are obtained. This represents a draft on the furnace of about, say 0.25 in. I now turn the wick of the lamp higher again, till with this 14 in. chimney it again begins to smoke. We will now put the 10 in.

chimney over the 14 in., making a new height of about 20 in. The smoke again ceases, the flame is now enormous in size and very white in color, showing very rapid combustion and very

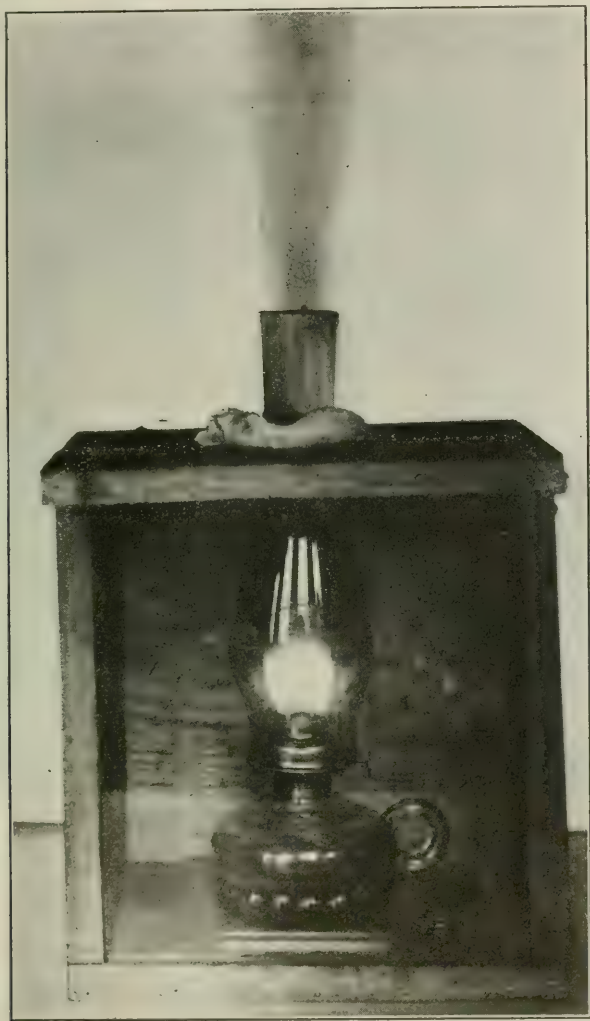


Fig. 10.—The Same as in Previous View Except That the Glass Front of the Box Is in Place, Obstructing Air Supply to the Lamp, Except Such Amount as Gains Admission by Leakage at Joints.

high temperature—probably from 2,200 to 2,400 degrees,—while the one that we started with at the beginning, which burned like a torch, was probably not more than 1,500 to 1,600 degrees.

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These experiments show that if a proper draft is provided for a furnace much more heat can be developed from the same amount of fuel burned than if the draft is low. The limit on draft over the fire is 0.3 in. or 3.35 inch. This is as high as practical in usual stationary practice, as more draft than this will burn holes through the fire. We should strive, in proper fur-



Fig. 11.—Showing Effect of Stopping of Air Supply from Below by Means of Handkerchief—Analogous to Closing Ashpit Doors of Furnace.

nace practice, to maintain a draft from 0.25 in. to 0.30 in. and keep the fire from 4 in. to 6 in. in thickness. Furnace temperature should be as high as possible, which will insure the uptake temperature being at a minimum.

Boilers and furnaces are of many designs, some vastly different from others ; so, to give the best results, they should be

handled differently. One important thing, however, that all boiler furnaces should have, is a combustion chamber between the grates and heating surface. In the case of this lamp, though the flame is burning brightly and making no smoke, if I drop an iron body down the chimney so that it comes in contact with the flame, smoke results. The cause is that the gases are cooled before the combustion is complete, as occurs when grates are located too close to the heating surface of a boiler, making it almost impossible to operate without smoke under such conditions. The foregoing has reference more particularly to the handling of the air, after it has been supplied to the fireroom.

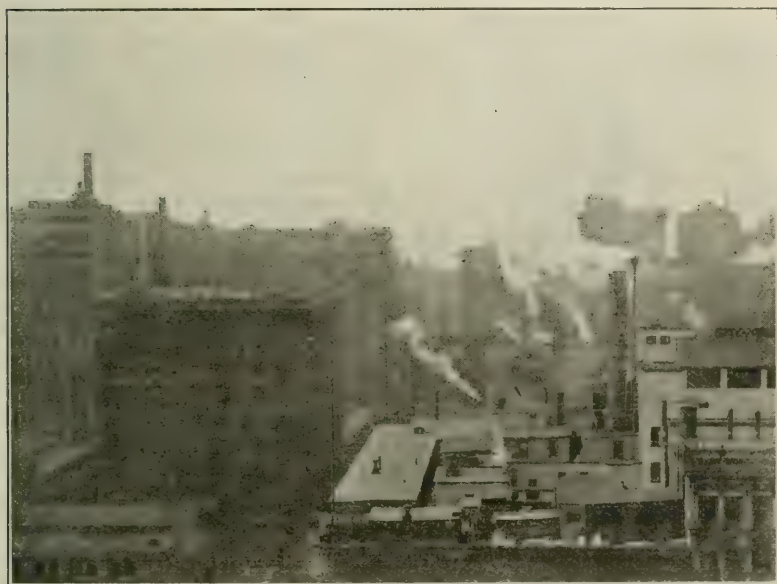


Fig. 12.—Representative View North from Fisher Building, Showing Absence of Smoke from Chimneys in Downtown District of Chicago.

The matter of introduction of air to the fireroom is of equal importance to its supply to the furnace, as we shall see by the continuation of my experiments. To illustrate, I will place the lamp, which is burning brightly, inside of this box which has three sides closed and the front open. At each side of this opening are grooves which will allow a sheet of glass to fit practically air-tight. We will place a cloth around the lamp chimney, closing the space where it passes through the top of the box. Then we will lower the plate of glass in the grooves and reduce the air supply to the lamp, with the result that the flame, which was bright before, now at once becomes red and bursts into smoke. This represents a condition which prevails

in Chicago today during cold weather in nine-tenths of all of our boiler plants. Doors and windows are kept shut to keep out the cold, and the only air the fire gets is what comes in through cracks and crevices, and while the doors are being opened and closed for admission and exit of persons. It is no wonder that the doors in our buildings open hard, that the windows leak cold air, and that the offices are hard to heat, because the boiler plant in the basement is trying to get air, and in doing so is drawing a vacuum on the whole building.

One cold morning when I arrived at my own plant they were having a hard time to heat the building. The telephone was constantly ringing from different offices, giving complaint that the rooms were cold. I started an investigation. My assistant engineer told me that an inspection of the whole building had been made, and that only three or four cold radiators had been found, which had been remedied. He said something should be done to the windows, because they were leaking so badly it was impossible to heat the offices. I told him to open the door in the boiler room to the outside atmosphere, so that the furnace could get air. As soon as he did this, the trouble ceased in twenty minutes. The offices warmed up, the windows stopped leaking, and the front doors opened much easier than before. Architects and consulting engineers, in laying out buildings and boiler plants, seldom provide openings for air supply to furnace rooms.

Although we may have an abundance of air in the boiler room and sufficient draft, we may still make smoke if the furnace is not well designed and properly operated. To the operation of hand-fired furnaces the following will apply:

Fire light and often. If the draft is weak, the fire must be kept much thinner than if it is strong, as the resistance through a heavy bed of fire is much more than it is through a light one. Do not shut ashpit doors or close the stack damper too much.

If the equipment is that of mechanical stokers, treat it as a stoker outfit and not as a hand-fired outfit. Allow the stoker engine to do its part. It is there for that purpose, and can do a better job of firing than can be done by a man. It will put the fuel into the furnace constantly and uniformly, and will discharge the refuse the same way if properly adjusted. The furnace should not be open half the time for the fireman to poke the fire, for if it is, the green coal will get down on the bottom and the ashes and clinkers on top of the fire.

The exhaust of boiler feed pump, as well as that of stoker engine, should discharge into the ashpit. This will keep the grates cool, make the clinker soft, assist combustion, and help maintain a clean fire.

A damper regulator should be attached to both the stack damper and the throttle of the stoker engine. It will prevent

the safety valve blowing and will regulate the speed of the stoker engine according to the amount of power required from the boiler. The more steam that is taken from the boiler, the faster the stoker engine will operate and the more fuel will be fed to the grate. The less steam taken from the boiler, the slower the engine will run, balancing the amount of coal in the furnace with the proper requirements. The damper regulator will work the same one day as it will another; it is attending to business all the time; it will stop smoke and save coal. In the plant I operate, the damper regulator described has saved a ton of coal every twenty-four hours, in addition to maintaining a steady steam pressure.

The gas analyzing instrument and the draft gauge are to the boiler what the indicator is to the engine. They will show where the trouble lies and how it may be remedied. If the  $\text{CO}_2$  in the uptake is from 12% to 14%, conditions are good; if down to 3% or 4%, as in many cases, conditions are bad.

*Mr. T. J. McNeill* (of Reid, Murdoch & Co.): I have had experience with the smoke problem in the down-town district for about ten years, and at this particular time I think I am somewhere within the law, if absence of notices and suit from the Smoke Department means anything; but perhaps I had better not boast. It is largely, however, a question of conditions. With different conditions I might get different results. But I have been very fortunate in the last two or three years. I am making at this time a very small amount of steam compared with some of the other plants down town, as we have moved our factory to Hammond, Indiana, where we can make all the smoke we wish. Here in Chicago we are making, with two Babcock boilers, twelve to sixteen thousand pounds of steam an hour. I am pleased to say that we are getting along nicely, and from my experience I think that smoke can be eliminated through the proper design and construction of boilers and furnaces.

*Mr. William Starr* (of Pettibone, Mulliken & Co.): My experience might not be such as to be of help in the down-town district, because we have almost ideal conditions. We have a new plant and are above the ground. We have plenty of air coming into the boiler room, plenty of high chimneys, a fair height of boilers over the grate, and all conditions are good. So far, I have had no experience with the Smoke Department in any way. When we started up some six years ago we did not smoke, because the plant was started as a hand fired plant, with steam jets over the grate. As the business increased we put in chain grates. The chain grates are set about one-half in front of the boilers, which are of the Heine type, with tile roof.

At one time, I think for about three or four days, I noticed the chimney smoking a little. I let it continue for three or four

days without saying anything, and then asked the fireman what the trouble was. He commenced making excuses, stating that the conditions were so and so, and that there ought to be some changes made. I said: "The conditions are the same as they have been, but if necessary I will make some changes, and the first change I will make will be a change of fireman." From that time on there was no smoke, showing that ordinary attention will operate such a plant as ours practically smokeless.

With our 200 ft. chimney, we get on the average about four-tenths of an inch draught at the fire. That we control, according to requirements, by a damper regulator; the regulator is so arranged that it does not close all of the draught, but is so set that we have at all times from 0.10 in. to 0.15 in. of draught, and for this reason the chimney does not smoke when the damper is checked.

*Mr. W. G. Lighty* (of the Schiller Building): I have been very much interested in the discussion. I believe that there has been a great deal accomplished in the last two or three years, especially in the down-town district, and I believe that a large portion of the results are due to the interest taken by the operating engineers, although I think much more could be accomplished if every engineer would take up the matter of educating his fireman. I think that this is one thing in which we are especially lacking in Chicago,—that of good, experienced firemen.

As far as the present smoke laws are concerned, I have no criticism to make. But there is a matter of which I wish to speak. The ordinance provides for the examination of plans of furnaces as put in, but it does not provide for any examination as to the way plants are kept up and maintained. I believe that inspection of this character would be beneficial. For example: we may have a furnace installed with the approval of the Smoke Department, but in the course of a year or two, or less, it is found that conditions have changed so that it is necessary to work the furnace harder, or alterations may be made in the furnace that the Smoke Department have virtually no way of finding out about.

*Mr. W. F. Strickler* (of the Coated Board Co.): Being the engineer of a plant out on the North Pier, with I believe the most prominent chimney in the down-town district, which has been heralded in all the newspapers as the most notorious smoker in the city, I would like to say a few words about this six minutes time limit in the ordinance, for this time limit in a manufacturing plant I maintain is impracticable. In my own case there are times every week when I will lose 50% of my load through an accident in the mill. We run twenty-four hours a day, and accidents will occur. If I lose 50% of my load, we must choke fires, our furnaces will become cool, and, as

Mr. Saxe explained a few moments ago, the temperature must be kept up to run it. Now, suddenly the load comes on again, and we must meet it, but we cannot get back to normal conditions in six minutes. Again, we may blow out a tube once in a while, or an arch falls in, and we must fire an idle boiler, and I do not think anybody will claim that an idle boiler can be fired up and put in commission in six minutes.

I think the Smoke Department (and they have been following me up pretty closely) will bear me out in my statement that I have made a very great effort to stop the smoke, and have succeeded in cutting out 90% of it. I make the statement here tonight that my plant runs 95% of the time smokeless, and that not more than 1% of the time is it running in violation of the ordinance.

Mr. Donnelley, in his talk the other night, stated positively that the Department would prosecute anybody making two violations within a month. On the other hand, he made the statement that they would not prosecute anybody that is trying to do all that is possible to prevent smoke. He also said that railroads are trying to do all they can, so he will not prosecute them. There are others who are trying as hard as the railroads, and accomplishing, I maintain, more than they have accomplished. So it looks to me as if discrimination were being shown. I do not see why the Department should show greater discrimination in the case of railroads than it would in the case of paper mills.

Now, that six minutes clause allows a man to make smoke 8% of the time. I do not think that the Smoke Department will admit that there are many plants down-town which smoke 8% of the time, yet, recently (I think it was on the 26th of October) I had a couple of flues burst in one of the boilers and had to fire up an idle boiler. Of course I made smoke while I did it. On November 3rd I had an arch fall in on the grate, and I had to fire another idle boiler. On November 9th I received a notice from the Smoke Department that it had authorized the prosecuting attorney to bring suit against us for smoke violations on October 26th and November 3d. I think that if the Smoke Department is to use discretion and judgment as to whether a plant is doing all it can to prevent smoke, they should call and see whether we are actually trying to prevent smoke, or whether we are just trying to hoodwink them. I think an investigation would convince them that we are trying to do everything possible.

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*Mr. John Weber (of Hillman & Co.):* I commenced to study the smoke problem and make experiments in the summer of 1888, while I was acting as the engineer of an electric light plant in the rear of the buildings at 31st St. and Indiana Ave., this city. The equipment, aside from the electrical apparatus and engines, consisted of two horizontal tubular boilers with common

furnace settings and flat grates. While the business men and neighbors were delighted to see the establishment of an electric lighting plant in their vicinity, the smoke nuisance developed so quickly that those who were our friends at the start became our worst enemies.

With the assistance of several brick masons, a type of furnace was developed that with a reasonable amount of care in firing, eliminated the smoke entirely. Right here I want to add that the particular masons whom I found to be most proficient in the—let us call it—art, of suppressing smoke were either Englishmen or Cornishmen. As I remember, they seemed to work from varied experiences, and while they could suggest that this or that kind of an arch, or diverting wall, might do so and so, none of them had any data whatever to prove the assertions made. After installing about ten different kinds of settings, making experiments from 1888 to 1891, and searching the patent office records of the United States, we decided to have an attorney make a search in the English office. We were rewarded with quite an exposition of diversified ideas in furnace design, but found ourselves as far from the real meat of the subject as we were at the commencement. In building and operating some of these, we discovered that most any kind of a diverging wall, baffle wall, or arch seemed to reduce the smoke emanating from the stack when the wall or arch was new, or almost new, and the various air channels were open.

After the furnaces were operated for some time, the fire brick walls or arches became glazed over, the air channels became plugged up, and the efficiency of the particular furnace as a smoke preventer was almost, if not altogether, destroyed. One particular type that seemed to give the best results was a type of bridge wall with tunnels of proper area running lengthwise through the same.

A combination of air channels with this type of wall was patented by myself and my father in 1889, and this type was known as the *Weber Perfect Combustion Furnace*. A company of that name was formed with offices in the Lakeside building.

About this time the *Chicago Daily News* became interested in the fresh air work, with which most of us are acquainted. The Weber Furnace Co. effected an arrangement whereby a sketch or drawing of this type of furnace was advertised by the fresh air editor of the *Chicago Daily News*, and permission was given the general public to put in such an outfit.

It was found that with this setting the application of fresh coal had to be followed by the sprinkling of common gas-house coke over the green coal in order to ignite the green coal smokelessly. Many of these furnaces were installed when it was discovered that after some months of use the smoke inspector began to recognize the existence of the user. Our hopes were shattered

and we realized that we were up against something we had not contemplated.

A German chemist was engaged to make a thorough investigation and give us some enlightenment as to why our settings proved so good at the start and gradually failed. As I remember the essence of his report, he said that the free carbon particles which are released from the coal in the first stages of distillation may be ignited if admixed with a certain quantity of air (which contains the oxygen that the green coal did not get in sufficient quantities while being heated to the ignition temperature), but that the admixture must be reheated in some manner before ignition of the new gas becomes a fact; that if the brickwork under the boiler is new, it absorbs and gives up heat rapidly and in giving up the heat it has absorbed while the fuel was incandescent, it reheats the new mixture of released particles of carbon and air and brings it up to the ignition temperature in its contact with the heated brick, to be burned in the combustion chamber; that after the brickwork has become glazed it absorbs and gives up heat more slowly, does not heat the free carbon and air mixture rapidly enough, and fails to ignite the newly distilled gas in consequence, which passes from the stack as smoke.

This will probably account for the numerous times that the owner has bought a furnace setting which worked long enough to warrant him in paying the bill for the installation and get soaked for a smoke fine afterward.

Since that time I have observed that there was a quantity of truth in the German chemist's theory, and I have noticed innumerable times that with a fresh brick setting, clean air channels, and a good fireman the problem of burning bituminous coal smokelessly is a fairly easy one, *but to obtain such a combination is not so easy.*

The man operating the fires is the largest factor in the whole combination, and the engineer who is responsible has often to render an account for the carelessness of the fireman. The chief engineer gets the diploma for carelessness in any and all events.

One great trouble I find in my experience with most employers is that after they get acquainted with the operating engineer who works for them, the advice and counsel given to the owner by the engineer is looked upon lightly and some outside influence and advice bears greater weight than the advice volunteered by the operating engineer. How many times does an owner make repairs to his boilers and elevators due to the reports of some engineer recommended by some business acquaintance, repairs that otherwise would not be made if they were requested by the engineer whose face the owner sees at the pay window every so often.

It seems to me that there should be a committee of operating

engineers appointed by some one in authority to work with the Smoke Inspection Department and to have regularly appointed inspectors, who will make inspections of furnaces and offer suggestions to the owners of such furnaces that will enable them to do intelligently that which is right and proper, so that the owner may be obliged to make the repairs and be in a position to *rightly* blame the engineer or fireman for making smoke. The inspectors' reports could be referred to the committee of operating engineers for suggestions, drawings, layouts, and advice. The operating engineer should have a voice in the law that is intended to control and punish him. It is not right to make a law setting forth that six minutes of dense smoke in any one hour is a violation, when the quantity of fuel consumed under the stack is not taken into consideration.

The usually overworked operating engineer has one more task placed upon his shoulders, and the gravity of the task must be made to soak into the owner, and also the smoke inspector. To appoint a committee of engineers whose duty it is to act as advisers is apparently all right, but the kind of operating engineers appointed must not be of the sort that are in positions where they give their orders from a distance, occasionally and semi-occasionally; but rather the type of operating engineer who lives part of his time in or near the boiler room. If a corps of furnace inspectors existed who put on the usual boiler inspector's garb and went into the furnace room, say every three months at least, and made reports to the owners, together with good, solid, tangible suggestions, I think it would be a long step towards the solution of the smoke problem, and towards assisting the operating engineer to solve his portion of it.

It is very easy for the Smoke Inspection Department to write letters, notifying the owner that he has broken the law,—a law that does not take into consideration how much fuel is consumed under the particular stack,—and then have the owner call the engineer to his office and hand him a notice of suit with an air indicating that the engineer had committed murder. But it is a different proposition when you happen to be the operating engineer, and are obliged to depend on a certain class of men to stand between you and the manifestations on the top of the chimney, who are unable to understand what you want to teach them. If, for instance, the fireman was licensed by the Smoke Inspector to operate as a stoker of bituminous coal, and he should lose his license and his job if he became careless after the owner and the operating engineer had taken due precaution, do you think it would help matters? I think it would.

*Mr. H. P. White* (of Seipp's Brewery): There is one thing that has been neglected. I have heard no one speak of the matter of clean setting of the boiler. A lot of the trouble we have been talking about is occasioned by dirt. There are many en-

gineers that do not keep their boilers as clean on the exterior surface as they should. If they will do this it will eliminate much of the smoke.

It would be a good thing if we had some way by which the fireman could get an idea of what is going out of his chimney. At present all he can do is to look into his fire; it may look fairly well to him, and still be making smoke. If there were some means whereby he could have a view of his stack,—something on the order of the recording smoke meter that is now on the market,—it would help the fireman to eliminate a lot of smoke. If he observes that he is making smoke, he will endeavor to learn the reason why. I think these suggestions are worth considerable thought.

*Mr. A. D. Shriner* (of Simmonds Manufacturing Co.): I am not prepared to say anything definite on the subject. I make smoke and I get a notice once in a while. Ours is a rolling-mill proposition. We do not know when we will have a load or when we will not. The six minutes time limit in the ordinance I think would justify some other provision, because there is not a person in the city of Chicago that has a range in his kitchen but that violates the smoke ordinance. Every time a fire is lighted, smoke is made for more than six minutes. We all understand that it takes four requisites brought together to make smokeless conditions,—space, mixture, time, and temperature. Unless we have the four together we are sure to make smoke, and it is pretty hard to get the four all together at the same time.

*Mr. E. H. Perry* (Sears, Roebuck & Co.): I have found out one thing, and if we stick to it I am sure we will do away with smoke; that is to complete the combustion of the fuel before the gases strike the heating surface of the boiler.

We have several conditions in our plant that are quite rare in Chicago. We have in the neighborhood of five or six hundred wagon-loads of rubbish, consisting of paper and boards, and this we have to burn. There are times when we make some smoke, we have done everything that we could to eliminate it, and I believe we have got as good a chimney as there is on the West Side.

*Dr. I. R. Wolfson* (Treas., Smith, Barnes & Strohber Co.): We have had quite a little trouble at our plant, but we put in another boiler and changed the grates. Another thing we did was to put in a sky-light, so that the fireman could see when he was making smoke. The engine and boiler rooms are off to one side of the building, and that sky-light is put right over the boiler, so that all the fireman has to do is to look up through it at his chimney and he can tell right away whether he is making smoke or not.

*Mr. C. F. Heal* (of the Borland Building): I have been expecting since the last meeting to get a smoke notice, but so

far I have not received it. I think the feature of the six minutes limit is one which interests most of the engineers. We cannot start up a fresh boiler without smoking more than six minutes. I was advised by one of the inspectors of the Smoke Department to fire up at night when we wanted to start a boiler. That would be violating the ordinance, however, even if the smoke were not seen. I would like to see the ordinance amended in this respect, so that we would have a little more leeway.

*Mr. E. A. Norberg* (of the Crane Co.): After hearing from Mr. Saxe, one would think that about the only thing you would have to do would be to install a stoker of some kind to prevent smoke. I used to think that myself until I began burning coal by stokers, and then I began to think that the way to prevent smoke was to take the stokers out. I believe that it does not make any difference to the stoker people how they are put in; they will install them in any manner as long as you have the price, and I know that they are sometimes put in so it will be an impossibility to operate the boilers without smoke. But I believe that boilers can be made absolutely smokeless; in fact, I have made one myself, and I should say that we cannot make smoke with this boiler if it is heated up and if the damper is left open. We have burned everything from screenings to block coal in it, and have never been able to make smoke after the boiler is heated up. I believe that if owners, when they install a new plant, would take the advice of their operating engineer more frequently, there would not be nearly as much trouble about this smoke nuisance.

We operating engineers spend two-thirds of our waking hours at the plant, yet some people think we know nothing about it. They will take the advice of a consulting engineer because he is supposed to know more about the problem than the operating engineer. I know that all the plants that are designed by operating engineers operate with a great deal less smoke than the plants that are designed by consulting engineers, and I believe the reason is that the consulting engineer is governed too much by the first cost. I heard a man say that the reason the plants in the city of Chicago do not operate right is because they do not cost enough, and I think that is quite true.

*Mr. C. W. Brown* (of the Armour Glue Works): The ground seems to have been pretty well covered, but there is one thing that I would like to speak of and that is fire brick. I think that the proper brick used in a furnace has as much to do with the chimney smoking as anything else. I believe that at our plant we made as much smoke as any plant in the city of Chicago up to within a few years ago, but under the pressure of the Smoke Department all that has been changed, and now I think we are complying thoroughly with all the requirements of the City. I notice that with a good quality of brick we are

able to run our furnaces six to nine months absolutely smokeless, and at the expiration of that time, they will have to be replaced.

*Mr. Edward Kcenan* (of the International Harvester Co.): At our plant we have done everything possible to prevent smoke. Most of our trouble comes from shavings, refuse, and twine, for that class of material is very hard to burn. We use all the way from 60 to 70 tons of shavings and saw-dust a day, and 180 to 225 tons of coal, and there are times when we get shavings faster than we can burn them. We have mechanical stokers, which have given very good satisfaction, and I believe this type of stoker is the solution of the smoke problem if it is put in right, handled right, and taken care of.

So far we have not been troubled much by the Smoke Department, although once in a while Mr. Bird will jog our memory by sending us a notice.

*Mr. J. W. Mabbs*, M. W. S. E. (of the Board of Trade): I would like to see the boiler furnace or stoker that can be fired up from a cold condition and not make smoke. It seems to me too, that it would smoke just as much when it is fired up after dark, as during daylight. What is the engineer going to do when he must fire an idle boiler? According to the law he must not make smoke more than six minutes in one hour. If he makes smoke more than six minutes twice a month, he is fined. Now, I would like to know from the Smoke Commission how much discretion is to be used in such cases.

I know of a recent case where a smoke device on a boiler went wrong, and the boiler began to cause smoke. The only thing feasible was to shut down, but the firing of another boiler would make smoke more than six minutes. There are many of these things that an operating engineer encounters which the man who built the chimney does not know anything about, or does not often take into consideration.

A suggestion was made at the last meeting which I think was an excellent one,—namely, that the Smoke Commission publish information that it obtains. This would be worth much to the engineers. The engineers, as a body, are heartily in favor of helping along the anti-smoke proposition, and I think there is not an engineer in Chicago but that will do all he can to help it along. At the same time there are a whole lot of things on the other side of the question. Often fires have to be cleaned. I should prefer to have half an hour once in ten hours when I could make smoke, than to have six minutes in each hour, because in half an hour I could have all our boilers cleaned, but it is pretty hard work to clean from one to six boilers and not make smoke more than six minutes. I admit that a furnace can be made that will not make smoke after it is started, but I have never yet seen one that can be fired up from a cold condition that would not make smoke.

*Mr. Otto Luhr:* It seems that most engineers expect furnaces to be fool-proof. Such a thing never has been and never will be. They will always require a certain amount of supervision by the engineer, including instruction of the fireman.

Mr. Saxe gave a very good demonstration of how to operate a kerosene lamp. A kerosene lamp is easy to operate, but a furnace, while the principle of its operation is the same, is more difficult to handle.

There is not sufficient stress laid upon the proper mixture of combustible gases and the incoming air. We have in most cases too much air going through the furnace, and whenever that condition occurs, the furnace temperature is reduced. Whenever we have sufficient air, we have high temperature as a natural consequence, but a proper mixture is not easily obtained. In order to get plenty of air through the furnace, all we need to do is to leave the doors open, or take the chimney off of the kerosene lamp as Mr. Saxe did, but we do not get it properly mixed. In a kerosene lamp we find a sieve underneath, which is there to admit the air in small streams; in other words, it acts as a mixer.

I think the Smoke Department has accomplished much by inducing engineers to set their boilers properly,—to put in an arch, for instance, and not let the gases come in contact with the cold surface right away, thereby securing a good mixture.

I gave this subject a great deal of thought some years ago, not because I wanted to, but because I had to. I have experimented a great deal, and have tested a great deal, and I had to instruct my own fireman how to operate the furnaces properly. It is not easy to instruct old firemen, for they generally fall back into their old habits. As a rule there are not sufficient instruments in the boiler room. In 95% of the boiler rooms there are no flue gas thermometers; the fireman does not know what he is doing for he cannot even see the chimney. The only guide he has is to look at the fire in front. Usually a fireman does not study the laws of combustion, so it is necessary for the engineer to study them, to instruct his fireman, and to show him how the furnace should be fired.

I will say this in favor of the Smoke Department, that it has done much to eliminate smoke. If I look back ten, fifteen, or twenty years in Chicago, I recall that we had a great deal of smoke, and owners could not be compelled to apply proper devices for suppressing it. Since the Smoke Department began compelling owners to do things right, we have eliminated the smoke to a great extent.

Of course, there are only three conditions that are required to produce perfect combustion,—sufficient air, high temperature, and proper mixture. If you get them you get perfect combustion. However, these conditions are not obtained easily, for how is the fireman to know whether he has sufficient air, just by looking at the fire? How can he tell whether, when the air

enters the furnace, if it mixes properly with the gases? As it is now, he may know only by experience.

## CLOSURE.

*Mr. Paul P. Bird:* The discussion of this paper has been so voluminous that there is but little that the author may add, and in most of it information of value has been contributed. I think that the most striking thing that stands out in all the discussion is in connection with the difficulties of smokeless operation of steam plants. Mr. McGrath's remarks about the early attempts made years ago to abate the smoke nuisance, and Mr. Bement's description of the various organizations and city officials who have joined in the smoke fight in the past, convince us that the problem is difficult and worthy of all the thought and study that we can give it. The fact that the discussion has been frank and to the point has pleased me, because it shows that every one is interested in the problem and is willing to do his share toward bringing about an improvement. Different engineers who have discussed the paper have made certain suggestions for improvement in the work of the City Smoke Department. In fact, after reading all of the discussions, the writer concludes that practically every suggestion that has been made could be carried out if there was more money available for the use of the Department. For instance, it was suggested that the Department should publish bulletins from time to time which could be circulated amongst engineers and every one interested, which might discuss various installations and illustrate designs of smokeless furnaces, boiler settings, etc. The Department has often considered this and would be very glad to do it if there was sufficient money available to pay for publishing and circulating the bulletins.

Similarly, it has been suggested that offenders should be notified at the time the smoke is being made. With the large number of chimneys and with the few outside inspectors to watch them, it has been found that it is entirely impossible to notify the engineers or owners of smoking chimneys at the time that the smoke is being made. The outside inspectors are able to cover so much more ground when they work as they do now, than they would under such a plan.

Mr. Bement, in his discussion, mentioned the fact that a great many chimneys smoke at night and on holidays that do not smoke at any other time, and that the Department should provide some means of preventing this. Again, we cannot afford to employ a night squad. Our appropriation only provides for fourteen outside inspectors, and we feel that there is so much work for them to do in the day time, that it is more important that they work at that time. The criticism is good, however, because we all know that many chimneys smoke at night and on Sundays, but during week days, when the smoke inspectors are at work, they are clean.

Mr. Johnson suggests that we extend our system of having experienced engineers, in the employ of the Department, visit the plants that make smoke and work with the engineer in charge toward discovering the cause of the smoke and eliminating it. Again the poverty of the Department comes in and keeps us from doing this. If we had sufficient men we would be able to have every violation that is observed followed up and the cause of the smoke discovered. The task of cleaning up the smoke of Chicago is such a big one that it would be possible to work a Department several times the size of the present one efficiently. With thirteen thousand chimneys which may sometimes make smoke, scattered over one hundred and ninety square miles, it would require a very large force to watch and follow up every violation properly.

Mr. Bement in his discussion outlined a certain classification of all stationary steam plants in Chicago which he suggested might be made. There is considerable of this classification and tabulation work that should be done by the Department if the men and time were available for the work. However, as in the other cases, our men are kept busy all the time on work that we feel is more important. In a few years from now the office possibly may make use of this classification or some other one. At the beginning of the Department's work, about two and one-half years ago, it was thought that all of the plants in Chicago might be grouped in various classes, and that the Department should hold plants in different classes up to different standards. Today, however, it is believed that this system is not the proper one. The policy of the Department for the last year has been to adopt a fixed rule in certain sections of the city, this rule applying to every plant and to every one in that section. In the central district, from Lake Michigan to Halsted Street and from Chicago Avenue to 22d Street, the *thirty-day rule* is now in force. This rule is, that whenever the records of the office show two or more violations by the same plant within thirty days, suit is started. The rule is enforced on all alike. The chimneys of all buildings, factories, locomotives, tugs, steamships, etc., in this district, all come under the same rule. It is believed by those in charge of the work that such a system is better than to group plants into different classes and have a different rule for each class. It may be harder to keep down smoke in a tug boat than it is in an office building, but both stacks are in the center of the city and the smoke from one is as much of a nuisance as the smoke from the other.

Two or three of the engineers who took part in the discussion felt that the six minutes of smoke that plants are now allowed to make in one hour, is too small a margin for use in the manufacturing districts or during the hour when fires are being cleaned. The author feels that six minutes is a liberal enough allowance when the manner in which the violations are observed

is considered. If we were able to have men watch all the stacks in the city all the time, and suits were started on every violation of the ordinance that was reported, it might be considered to be too severe an ordinance. However, when one cannot even see a stack once a day I do not feel that the requirements of this ordinance are stiffer than advisable.

Mr. Naylor called attention to the smoke that is made by city buildings, such as the public schools and pumping stations. While it is true that these two classes of buildings are frequent violators of the law, it is also true that there has been a very great improvement in the smoke conditions at the school houses and pumping stations during the last two years. The schools in Chicago have not been as free from smoke in years as they were during the winter of 1909-1910. Similarly, with the pumping stations, they are making less smoke today than ever before. It is quite true that there is room for improvement, but it should not be felt that the City is not trying to stop its own smoke.

Mr. Naylor also felt that the City should compel the installation of automatic smoke recorders so that the engineer would have some means of knowing when his stack was smoking. I feel that, as long as smoke recorders are such newly devised instruments and have not yet been tried out under all conditions, it would be impracticable for the Smoke Department to consider such a rule. I am very much in favor of the use of smoke recorders and feel that in a great many instances, particularly in office buildings, devices of this sort are quite necessary. However, I do not think that the time has come when the City should compel the installation of such instruments.

In his discussion Mr. Bement has given some interesting data on the history of the smoke prevention movement in Chicago. It is desirable that this information be put on record, and I am glad that it has been presented in the discussion of this paper. He suggested two changes relative to the organization of the Smoke Abatement Commission. First, that one of the members of the Commission be an engineer, and second, that another one of the members should be a member of the city administration. These suggestions might make the Smoke Abatement Commission stronger in some ways, and yet I feel that it would be difficult to find a group of men who would be more efficient and more unselfish in their work than the members of the present Smoke Abatement Commission.

Mr. Bement also suggests that the ordinance be revised and thoroughly gone over. In my opinion, too, this should be done. However, during the past two and one-half years we have felt that as long as the ordinance allows us to go ahead with the work along the lines decided upon, it is better to let well enough alone and first get all of the plants in the city within the requirements of the present ordinance and then draw up another one.

## WOOD PRESERVATION FROM AN ENGINEERING STANDPOINT.

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C. T. Barnum—U. S. Forest Service.

*Presented, October 6, 1909.*

For a number of years engineers throughout the country have been confronted with the fact that the supply of timber for structural purposes is being rapidly exhausted, and they have been compelled to give serious consideration both to conserving the present supply and to developing other materials to act as substitutes.

That much energy and thought has been given to the substitution of other materials for wood is evident when we consider what has been accomplished. In this work the use of steel and concrete, both separately and in combination, has undoubtedly far exceeded that of all other materials. The vast quantity of reinforced concrete now used for all kinds of buildings and construction purposes, the amount of steel used for towers and poles in electric transmission lines, the number of steel and concrete bridges, and the growing popularity of steel for the construction of railroad cars, indicate only a few of the many ways in which these materials have been successfully utilized. Experiments are being carried on continually to extend these uses, and there is every reason to believe that much more will be accomplished. The effect of this substitution on the growing demand for structural timber is enormous, but in spite of this successful substitution the demand for wood as a structural material has steadily increased from year to year. In illustration of this increasing demand for timber, the Forest Service estimates show that the lumber cut of the United States increased from eighteen billion board feet in 1880, to forty billion board feet in 1907. In view of these figures it is safe to assume that it will be a very long time before we find ourselves able to do without it.

There is another factor to be considered in the substitution of inorganic materials for wood. The limited supply of these materials must be kept in mind. Iron, for example, once taken from the mine is gone and cannot be renewed. Wood, on the other hand, is capable of growth and hence of indefinite replenishment from the same area. This fact will cause metals especially to rise in value, so that the ratio of cost between them and wood for construction purposes is a sliding and ever-changing one.

It is to be regretted that the energy which has been devoted to conserving our wood supply has not been equally as strong as that devoted to finding wood substitutes. Why it

has not met with the same consideration is hard to determine, but the fact remains that in view of its importance only indifferent attention has been given to it. For certain classes of construction wood is, on account of its inherent properties, best adapted for use, and it has so far resisted all attempts to displace it.

For railroad ties, telephone and telegraph poles, piling, mine props, and structural lumber, wood has shown its superiority. The extensive use of other materials for these purposes, of course, cannot be overlooked. Steel and concrete railroad ties, reinforced concrete and glass poles, steel and concrete piles and mine props are instances of this. In 1907, 572,233 steel ties were sold by one company. This company claims that the steel tie is no longer an experiment. Very much the same progress has been made with other forms. Reports from various users of this material, however, show that uncertainty of successful substitution still exists and the general impression throughout the country is that considerable more experimenting must be done before satisfactory substitution is accomplished.

This brings us back to the consideration of our timber supply for use in these particular cases, and when we consider the amount of wood consumed here its importance is seen to be justified.

Census statistics shows that in 1907 the steam and electric railroads of the country purchased some 153,000,000 cross ties, the telephone, telegraph, and other electric companies purchased over 3,500,000 poles, and it is estimated that throughout the mines in this country over 170,000,000 cubic feet of round mine timber was used. There are no reliable figures to show the production of timbers intended for use in the construction of bridges and for use in piling, but it is estimated that for the latter at least 2,000,000,000 feet were used. When we consider that these products constitute less than one-fifth of the total volume of lumber cut we get some idea of the enormous drain on our timber resources. It is further estimated by the Forest Service that the rate of cutting at the present day is exhausting our resources at the rate of about three times their growth. It is quite evident, therefore, that unless some radical changes be made a serious shortage of structural timbers is inevitable. This is especially true of the harder and more durable woods. The supply of this better grade of timber, which through its own properties resists decay for a reasonable time, is rapidly waning and in consequence its price in the market is rising. The average price of white oak, for instance, increased at the mill from \$13.78 per thousand feet in 1900 to \$21.23 per thousand feet in 1907, or 59 per cent. Leading lumber dealers, railroad managers, mine superintendents, and other consumers of timber for struc-

tural purposes, are accordingly turning their attention to ways and means of substituting cheaper and more plentiful kinds of timber for the better and more durable grades. Thus, where specifications once rigidly insisted upon first quality white oak for ties, or heart longleaf pine for dimension stuff, they are now given a very liberal interpretation, and other species than white oak are accepted with no difference in price, or considerable amounts of sapwood are allowed on "all-heart sticks."

This deterioration in quality naturally results in a decreased length of life, which in turn compels a large annual cut of timber.

#### TREATMENT

A feasible and effective way of relieving the situation is by the treatment of the timber to protect against decay. A successful treatment of this sort, provided the cost can be kept within economical limits, will, in the long run, not only greatly decrease the cost to the consumer, but will also tend to decrease the annual demands on the forest. A proper preservative treatment will prolong the life of decay-resisting species as well as those of an inferior grade. If all ties, poles, posts, piling, mine props, shingles, and structural lumber adapted to treatment were given an efficient preservative treatment, an estimated annual saving of five million board feet would ensue. The practice of preservative treatment will also create a new and increasing market for many timbers not formerly used, and timber consumers will more easily break away from their former custom of adhering closely to a few well-known kinds and disregarding others which may be equally as good in other respects but lack durability. Moreover, there will be an increasing realization that by the use of cheaper woods properly treated with preservatives, as good or better results can be obtained, together with the reduction of the annual cost. This last item, the saving in dollars and cents, is the all-important factor of wood preservation. As soon as the consumer fully understands that his annual expenses can be actually reduced by these methods, it is only natural to conclude that a strong effort will be made for their adoption.

Wood preservation is an exceedingly complex subject, and upon considering it many problems arise for solution. There has been a great deal of thought given to it, and it has undoubtedly made rapid strides during the comparatively short time it has been practised in this country. Nevertheless, it is still far from being on a sound scientific basis. The experiments that have been made show very clearly that each different species of wood, and wood of the same species but differing in the character of growth, present an entirely different set of problems. They differ greatly in the receptibility of different preservatives and they differ in the kind of preparation necessary for treatment and in their action in contact with the preservative, and after. The

kind and condition of wood to be treated and the conditions under which it is to be used are very important factors in determining the kind of treatment that is best. The effect of the preparation and of the preservative on the mechanical properties of the wood are also very important, and must be carefully considered before any treatment is decided upon. Present practices are now largely determined by the experience derived from preceding years rather than an intimate knowledge of the theory of the subject. This latter feature, however, is most important and is at the present time receiving much deserved consideration. The Forest Service in its laboratory now being erected at Madison, Wis., expects to study very comprehensively the different theoretical questions arising in this work, and it is hoped that this will result in extending our knowledge of the action of different preservatives and the way they should be applied to each species of timber to secure the best results.

During the early period of wood preservation in this country, the expense of the treatment and the necessary apparatus and the lack of reliable information regarding the results prevented to a great extent its extensive adoption. As the demand for it increased and more reliable figures were obtained regarding the actual increase in life from various treatments, the economic results were better understood. This led to a larger development, and at the present time there are over sixty wood preserving plants operating in the United States, with an output, in 1907, of one and one-fourth billion feet.

#### PRESERVATIVES

Of the many antiseptics which at one time or another have been proposed for the preservation of timber, two different classes may be made: (1) Antiseptic salts and various substances, such as zinc chloride, corrosive sublimate, and copper sulphate; and (2) antiseptic oils, of which creosote, or dead oil of coal tar, is most generally used. The most common preservatives in general use are zinc chloride and creosote, and both are excellent antiseptics. It may be said, however, that the principal value of zinc chloride is its cheapness and its ease of transportation, for it can be hauled in the form of a solid and dissolved at the treating plant. The principal defect of zinc chloride is its liability to leach out of the timber when exposed to moisture either in the soil or in the atmosphere. It readily dissolves in water and so its subsequent leaching out is merely a question of time, and the wood is left once more subject to attack. Its use, therefore, is limited to less moist situations. Creosote, on the other hand, is practically insoluble in water, so when a high grade of oil is used and injected into the timber, decay will be postponed almost indefinitely. Its principal disadvantages are its higher first cost as compared with zinc chloride, and its limited supply and the subsequent difficulty in getting a good grade.

In treatments for many structural purposes, such as piling and timber in wet situations, and especially where a long life is desired, creosote undoubtedly has demonstrated its ability to give the best results. Upon examination of certain timbers that have resisted decay for a long time, it has been learned that it is the heavier constituents of the oil that have remained in the wood, and it is therefore concluded that these constituents are to be depended upon in preservation work. For this reason, it is considered advisable that when specifying for creosote the heavier fractions should be called for.

#### TREATING PROCESSES

Treating processes as practiced today may be divided into two general classes: those which use pressure, and those which treat without pressure. Both of these may be subdivided into what is known as full cell and empty cell processes. The pressure process is too general and too well known to need description here. It is the more widely used of the two and without doubt the more effective for work on a large scale, and where a variety of woods must be treated. Pressures above 175 lb. per sq. in. are seldom exceeded in these plants, as with proper preparation practically all woods can be treated with this pressure, and for many woods less is needed. The quantity of treated wood required determines the volume and size of the apparatus used and its cost. A plant of this kind having a capacity of about 3,000 ties per day would cost about \$40,000 to install. Within the last year or so there has been introduced a plant in which only a medium amount of pressure is used. This type may be called a medium pressure plant. In it pressures ranging from 50 to 100 lb. per sq. in. are used. It is principally adapted for use by mining companies or city traction companies, where woods of a porous nature not especially resistant to the entrance of the preservative are used. Such a plant would usually be of a much less capacity than the ordinary plants, on account of being designed for the treatment of special classes of timber for local use, and can be built more cheaply on account of being of lighter construction. A plant of this type, with a capacity of 1,500 ties per day, would cost, approximately, \$20,000 to install.

Plants which treat without pressure are rightly called non-pressure plants. This type of plant is not the open-tank proper like that used in the treatment of butt telephone poles, but a closed cylinder similar to those of the pressure and medium pressure plants, but made of very much lighter material, usually  $\frac{1}{4}$  inch iron. The Forest Service has done much to develop this latter plant, because this process has filled a real need, a need which the pressure process could not fill. The development of this non-pressure process is due very largely to the heavy expense involved in the purchase and installation of the pressure plant, an expense which confines such plants to large commercial com-

panies or to companies such as railroads, which demand a very large and fairly constant supply of structural timber, comparatively resistant to the entrance of the preservative. It is not to be understood that this non-pressure process is to replace in any manner the older and more firmly established pressure processes for all timbers and conditions.

What was needed was a process by which the more porous lumber of different kinds and for different conditions could be treated efficiently and cheaply in a plant inexpensive to install and simple to operate. The record of attempts to meet this need is the history of the non-pressure process. This type of plant generally has a treating cylinder 6 feet in diameter and about 50 to 60 feet long, and a capacity of about 500 ties per day. It may be completely installed for from six to eight thousand dollars.

For the butt treatment of telephone and telegraph poles an ordinary open tank, either rectangular or round, about 9 feet in diameter by 9 feet deep, and fitted with steam coils, is used. A storage tank of small capacity for holding a supply of the preservative, and a jib crane for handling the poles in and out of the treating tank, complete the equipment. Such a plant can be installed for eight or ten hundred dollars.

A full cell treatment or process occurs when the wood cells and intercellular spaces of the timber are completely filled with the preservative. The portion of the timber treated in this case is made to take as much of the preservative as the cells are capable of containing.

On account of the expense involved in a treatment of this kind, with a preservative as costly as creosote, means have been sought to remove from the timber a portion of the preservative injected. In this manner the same penetration is secured with a much less amount of the preservative, and the cost of the treatment is consequently decreased. In treatments of this kind the preservative contained in the cells proper is withdrawn, and the cell walls left simply coated or painted with the preservative. This process is used largely in treating railroad ties with creosote, where mechanical wear destroys them before the increased life to be derived from a full cell treatment can be obtained.

#### LENGTH OF LIFE

The length of life of treated timber, like the treatment, depends on a variety of conditions. The kind of wood, kind of preservative used, the kind of treatment given, and the conditions under which the treated timber is used; all have an important bearing on the length of life. In the southern states, Louisiana and Texas particularly, a loblolly pine tie untreated will last little more than a year. Ties treated with zinc chloride and placed in a track in the same locality have been removed in three years on account of decay. The life of the same species of tim-

ber in one section of the country will not be the same when exposed to the climatic conditions in another section. The use of zinc chloride as a preservative does not give as long life as creosote. Ties properly treated with this can, however, be made to give an average life of about 12 years. In the Central West, hemlock and tamarack ties treated by the Wellhouse process have shown a life of twelve to fourteen years, while untreated ties under the same conditions have to be removed at the end of four years on account of decay. Properly creosoted ties can be made to last until destroyed by mechanical wear, and if protected against this wear can be made to give 20 to 30 years' service. With the proper kind of treatment, a pile can be made to last from twenty to twenty-five years. The L. & N. R. R. Company in 1882 used large quantities of creosoted piles, stringers, and caps in the construction of trestles and docks in the vicinity of Pensacola, Fla. All of this material gave a service of over twenty-five years. The New Orleans and North Eastern Railway Company's bridge across Lake Pontchartrain is another notable example of the efficient service to be expected from a good treatment. This bridge was built in 1876 on creosoted piling most of which today is in a good state of preservation. Most of the timber used in these instances was southern pine which, if untreated, would be destroyed by marine borers in 3 years or less. At Girardville, Pa., in the Reading Coal Company's mine, treated timbers have given 12 years' service where ordinarily they would be removed in 2 years.

The Forest Service has estimated that proper preservative treatment will increase the life of ties over 200%, poles 100%, posts, 300%, piles 700%, mine props 400%, and lumber 300%. These figures are made up of the average estimates of treated and untreated life for the various forms all through the country and under all conditions, so they naturally give merely an indication of the results of treatment which, in specific instances, may be much more or less than the general average.

#### ECONOMIC CONSIDERATIONS

It has been clearly demonstrated that the life of timber in many situations has been increased at least two-fold by the use of preservatives, and often the increased life is very much greater. Suppose, for example, that certain timbers put to a certain use will last 5 years without treatment. Disregarding interest charges, it is therefore true that the cost of treatment must be less than the additional cost of new timbers 5 years later, plus the cost of their setting in order to effect a saving. In treating on a large scale the additional cost of any treatment now practiced does not usually exceed the present purchase price of the timber. Therefore, the saving means at the least the cost of resetting the timbers, plus the advance in price of the timber, over a period of 5 years. For example, the popular grade

of mine timber in the West has increased some 40 to 50% in price within the last 5 years, and it is reasonable to suppose that a corresponding, if not greater, increase will occur within the next 5 years. Therefore, the financial saving from a treatment, which will double the life of the timber, will be equal to the cost of replacement, naturally a variable quantity, plus 50% of the present cost of timber. More frequently a good treatment will triple and quadruple the life, and the financial saving is correspondingly greater. Another factor entering into the economic value of the treatment is that often replacement of timber is an expensive undertaking. It means in some cases a shutting down of work on hand during the period of replacement, with the consequent more or less serious financial loss. For instance, the replacement of the timber in a mine shaft will often partially, if not wholly, stop all the work through that section during the period of replacement, with a corresponding financial loss to the company. Since by treatment these replacements may be easily reduced by one-half and oftener to a greater extent, it can be seen that this element bears an important relation to the financial saving growing out of preservative treatments.

With railroad ties a wide field for the betterment of conditions exists in the more general introduction of preservative treatment. Formerly, white oak was the most popular and widely used species for this purpose, but in the past 10 years the cost of the oak tie has more than doubled, and railroads have consequently been turning their attention to other species. Thus loblolly and shortleaf pine in the South, hemlock and tamarack in the Lake States, lodgepole pine and Engelmann spruce in the West, birch in Wisconsin and the New England region, and maple and beech in Michigan, Pennsylvania, New York, and Vermont, are gradually attaining recognition and rarely fail, when properly protected from decay and mechanical wear, to give satisfactory results. For example, it has been estimated by the Chicago and Northwestern Railway Company that the cost of the average untreated hemlock or tamarack cross-tie, when laid for use west of the Mississippi, is 75 cents. The cost of a satisfactory impregnation with zinc chloride is about 12 cents per tie, making the cost of the treated tie 87 cents.

The annual charge on an untreated tie costing 75 cents is 16.8 cents. For a treated tie costing 87 cents and lasting 6 years, the annual charge is 16.6 cents; lasting 7 years, 14.5 cents; lasting 8 years, 12.8 cents; and 10 years, the estimated life of a treated tie is 10.7 cents. These figures demonstrate that an added life of a single year makes the cost of treatment practicable and an added life of 5 years (a conservative estimate) secures a saving of 36.3% in the annual charge. By the substitution of a creosote for the zinc chloride treatment, although somewhat increasing the initial cost, the tie can be conservatively counted

upon to resist decay for 18 years, and this added length of life will amply repay the extra cost of the treatment.

By proper preservative treatment and the prevailing rates of interest, it can be conservatively estimated that the net annual saving for each form treated would be about 3 cents for a tie, 9 cents for a pole, 1 cent for a post, 2 cents for mine props, and about 50 cents per thousand feet for lumber. This would result in a total annual saving of about \$71,780,000. This includes the cost of labor as well as that of the timber itself, and this represents the amount of money that could be turned each year into other channels if wood preservation were uniformly adopted throughout the United States. It must be remembered, of course, that these figures are made up of average estimates of untreated and treated life, and naturally cannot be applied to specific cases.

Wood preservation, then, accomplishes three great economic objects: (1) It prolongs the life of durable species in use; (2) it prolongs the life of inferior and cheaper woods and thus enables the utilization of those inferior woods which, without preservative treatment, would have little or no value; and (3) it reduces the annual charge and renewal charges whenever it is used, enabling the money saved to be put to other uses.

#### DISCUSSION.

*President Allen:* The establishment by the Forest Service of a laboratory for testing processes and materials for wood preservation is certainly an important step in the art. So far, such experimental work has been carried on by different interests in various parts of the country and the results have often been limited by lack of resources. It will certainly be a great privilege to be able to call on a central experimental plant, where efficient apparatus has been installed, and where all kinds of preservative materials and woods are available for use. Of course it is too early now to speak of the results; these will depend on the way the station is operated and largely, as Mr. Barnum has said, on the coöperation of engineers and users of timber generally.

Several papers have been presented before this Society in the past on the subject of wood preservation. The first one was by Mr. Samuel M. Rowe, in 1899, and Mr. Octave Chanute presented one in 1900. Mr. Chanute is with us this evening, and I am sure we shall be very much pleased to have him open the discussion.

*Octave Chanute, HON. M. W. S. E.:* I have listened with much interest to Mr. Barnum's paper. After an experience of some 24 years in the preservation of wood, I will say that results depend largely upon the thoroughness with which the work is done. When we began work along this line the results obtained were not nearly as good as those we are obtaining today.

simply because we had not had the necessary experience. We followed at that time the German practice of injecting about one-third of a pound of chloride of zinc to the cubic foot of timber, and an average life of  $11\frac{1}{2}$  years was obtained with hemlock and tamarack ties. Since then we have ascertained that the Germans, in their extended experience, have increased the dose to one-half pound of dry chloride of zinc to the cubic foot, and with that we are now obtaining results (only 10 years old, however) which promise a life of 14 to 17 years in the track.

We also found that in the early days we treated the ties too soon, and did not allow them to be sufficiently seasoned to become entirely saturated throughout with the antiseptic treatment. I feel confident now, with the knowledge we have acquired, that we are going to get results with zinc-treated ties which will compare favorably with, although they will not equal, the results to be obtained with creosote. If creosote be thoroughly injected into wood with the full-cell process, the results which have been obtained in Europe show that a life of 20 to 27 years can be obtained. But there is one element there which does not obtain in this country. The rolling stock on the European railroads is light; the weight per wheel is limited to about 10,000 pounds, while the weight of our modern freight cars is much greater, for instance, a car weighing 49,000 pounds and carrying 100,000 pounds will give wheel pressures of about 18,000 pounds per wheel. Those weights are all producing mechanical wear, so that the ties, whether treated with zinc chloride or creosote, are going to be destroyed by mechanical wear sooner than by decay. Therefore, the problem of preservation also brings up the problem of better track, which I hope will be given due attention by the engineers of railroads.

*D. W. Roper*, M. W. S. E.: With regard to wood preservatives of various kinds, I would inquire if any of the preservatives mentioned have any active chemical properties which might injure metals which come in contact with the preservative?

*Mr. Barnum*: As to action of preservatives on iron and steel, creosote has no action that I know of. It does not cause deterioration in the iron cylinders or iron tanks in which it is used. Zinc chloride does; there is present in this solution a certain amount of free hydrochloric acid, and it is this that attacks the iron in the treating cylinders and tanks. The action is more severe on wrought iron than on cast iron; it will eat through a  $\frac{1}{4}$ -in. tank in 7 or 8 years.

*Mr. Roper*: Would that occur with railroad spikes?

*Mr. Barnum*: I have never heard what action zinc chloride solutions have in that connection. It might weaken the spike, but I do not know of any instance where this has occurred.

*Mr. Chanute*: If any of those present are thinking of trying to prevent the action of hydrochloric acid, I will say that

the simplest thing is to keep in the storage tank a slab of zinc so as to take up every particle of free acid. We have practiced that method continually, with the result that we have on hand a venerable cylinder, which is now 20 years old,—not much good, I will admit, but still it can be used,—and our cars last from 7 to 8 years. We have had more trouble from the use of the peculiar grade of creosote which we have imported from Germany, which contains 25% of tar-acids, and which has eaten the iron more rapidly than the zinc chloride.

*W. W. Curtis, M. W. S. E.:* With reference to the hydrochloric acid in properly made chloride of zinc, there is no free acid. I have tested for it a number of times without having found it.

As to the action of zinc chloride on metal; I think it is due to the fact that the zinc chloride is a deliquescent salt and tends to maintain a condition of moisture in the wood, which may have some effect on spikes. But so far as the effect on the storage tanks is concerned, I think we may consider that there is none. I have used steel storage tanks with zinc chloride of 60% strength, and if the tanks are given any kind of care at all, one can figure on their lasting for 10 or 12 years. There is a deterioration of the cylinders and of the cars in plants using zinc chloride, but in my judgment it is not the result of action of any acid, but of the atmosphere, acting on a surface, which is alternately wet and dry. A cylinder is subjected perhaps three times a day to steam, then to a solution, and then to air, and there is that same condition in connection with the cars, with the consequence that they rust. To my best knowledge this action is from oxidation and not from the effects of acid.

I have been interested in listening to the paper this evening, but the author is more enthusiastic than I have ever felt it safe to be. The conditions surrounding the life of treated timber are so variable, and the life is so modified by those conditions, that it is difficult to speak positively as to results.

I used to say, years ago, when it was more difficult to convince people than it is now, that one could rest perfectly secure in the proposition that he would secure as long a life with ties made from inferior wood, treated with zinc chloride, as he would from white oak ties untreated. That statement was sufficient, in my judgment, to justify any and every railroad company in adopting treated timber, and it was a conservative statement. At this time there is not much difficulty in convincing railroad companies that it is desirable to treat timber,—particularly railroad ties. There has been a wonderful change in thought along these lines in the last few years.

The results of some of my investigations made about 12 years ago indicated that up to that time there had been treated in this country, all together, less than 10,000,000 ties. Since then,

plants that I have built myself have treated nearly that many ties in one year. I have not seen the statement of statistics, but should be very much surprised if 15,000,000 ties were not treated last year in this country.

The Forest Service has been doing very good and valuable work, but I am free to confess that I think they did better service 3 to 5 years ago than they have within the last 2 years. Many problems in the treatment of timber have been solved, but there are many still unsolved. The department in past years has devoted its energy largely to attempting to solve such problems as the determination of the length of time the ties should season before treatment; the relative amounts of the salt solutions which could be injected with varying lengths of seasoning, etc., but it seems to me the Forest Service, in the last 2 years, has forgotten the purpose of its vocation, has gone outside of its sphere, and is becoming a commercial organization, rather than a scientific one as it was originally designed to be.

My attention was called, last spring, to a plant built in southern Ohio, described in a paper by one of the employes of the Forest Service, which he said was designed and built by the Forest Service. Shortly after that my attention was called to a letter received by a railroad official from an officer of the Forest Service, soliciting business for a timber-treating plant which it was announced the Forest Service had decided to build in Montana, the idea being to treat ties for the railroad company; or, if the railroad company preferred to build its own plant, the Forest Service offered to furnish plans and specifications, and all information and instruction, gratis.

There are a few engineers in this country who have attempted to develop a business along the lines of timber preservation, and it seemed to me somewhat incongruous for such men to compete with the United States Government. Finally I wrote to Secretary Wilson and called his attention to these facts. I told him that when I began my investigations 12 years ago in connection with this matter I had hoped to have something to do with the development of the business; that the Department of Agriculture was doing absolutely nothing in this line at that time, and it was some years after that before they actually took up the matter; that they had done good work in the way of reports which had been written and which contained a great deal of valuable information, but that that was some years ago. I asked him whether conditions had reached the state where professional men must compete with the government. Mr. Wilson said I was entirely right; that it was not the province of the government to compete with engineers or anyone else, and that the only reason that the department had taken up the matter was because, at the time they had done so, no one had succeeded in showing that soft-wood ties could be treated successfully so

as to preserve them from decay. I then wrote Mr. Wilson that it was well known how to treat a soft-wood tie, but that what we did not know was how to properly treat a hard-wood tie. Shortly after that I received a pleasant letter from Mr. Hall, Assistant Forester, repeating the statement that the department had no desire to compete with the engineers, and that it was only in special conditions they were assisting in the construction of plants. I asked him for what reasons the proposed plant was considered desirable in Montana; also for what reasons the plant had been designed and built for southern Ohio, but the answer was not satisfactory.

My attention was called recently to a paper which had been received by one of the railroad companies in Chicago, entitled "Suggestions for Treating Railroad Ties with Wood Preservatives for Railroads in Eastern and Central States," dated June, 1909. There are some remarkable statements in the paper, and I wrote to Mr. Hall and asked whether it had received the approval of the department. His reply was to the effect that they were unable to identify the paper, and asked if I would send a copy to him. I was rather surprised that they did not recognize their own child. As yet I have not been informed that the paper has been disowned.

The report is in most respects reasonably accurate; it describes the various classes of timber that can be treated; it gives in great detail the cost of treatment and resulting life both of the untreated and the treated ties; it gives a description of the various classes of treatment, etc. Then I found something which rather surprised me. (It might be well for me to state here that I have no interest in any process of creosoting ties.) I found in that paper a description of the empty-cell process. The empty-cell process as ordinarily understood is represented by two patented methods,—the Rueping and the Lowry.

The Congress of the United States, in 1790, concluded that it was wise to adopt a patent system in this country, and some people have endeavored to show that our prosperity has been largely based upon the monopoly for a term of years, secured to inventors by that law, which has been amended several times, but never repealed.

I will read a paragraph, which I found in the "Suggestions."

"The empty-cell processes at present most generally practiced—namely, the Rueping and the Lowry—are patented. For their use a royalty is charged,—2 cents a tie for the former and what amounts to from 6 to 9 cents for the latter. It is probable that the payment of these royalties is unnecessary. For the treatment of 750,000 annually, they would amount to \$15,000 for the Rueping and at least \$45,000 for the Lowry treatment. The Forest Service has had experience in devising methods of empty-cell treatment, and

the results obtained strongly indicate the possibility of devising practical empty-cell processes which will not infringe on existing patents. For instance, two years ago a member of the service devised an empty-cell treatment for cross-arms. By the introduction of a preliminary vacuum, a small technicality, the method of treatment was made distinct from a patented process. Again, an empty-cell treatment has been worked out for treating mine timbers which is based on a non-pressure process. Briefly, in the opinion of the Forest Service, it would not be good policy for the Company to adopt a patented empty-cell process without a most careful consideration."

That is, by the way, a misstatement of fact. The 6 to 9 cents mentioned includes not only the royalty but a profit on the construction and operation of the plant. "It is probable that the payment of those royalties is unnecessary." It seems to me a little out of place for one department of the government to use the public funds to try to undermine a system established by another and superior branch of the government. I do not know whether the Forest Service will have the patent laws repealed by the next Congress or not; probably it will.

I find in this report also:

"Ties of some porous wood, such as loblolly pine and black gum, can be treated effectively in a plant of comparatively light and inexpensive construction, equipped for the application of a low pressure (70 pounds). The Forest Service has designed such a plant for the Indianapolis, Columbus & Southern Traction Company, of Columbus, Indiana, and the Tennessee Coal, Iron and Railroad Company, of Birmingham, Alabama. A plant of the same general type but of heavier construction has been designed for the Great Southern Lumber Company, of Bogalusa, La. The capacity and estimated cost of these plants is as follows:

	Annual capacity	Maximum pressure	Estimated cost
(1) I. C. & S. T. Co...	180,000 ties	70 lb.	\$ 6,000
(2) T. C. I. & R. R. Co.	300,000 ties	70 lb.	15,000
(3) G. S. L. Co.....	450,000 ties	100 lb.	25,000

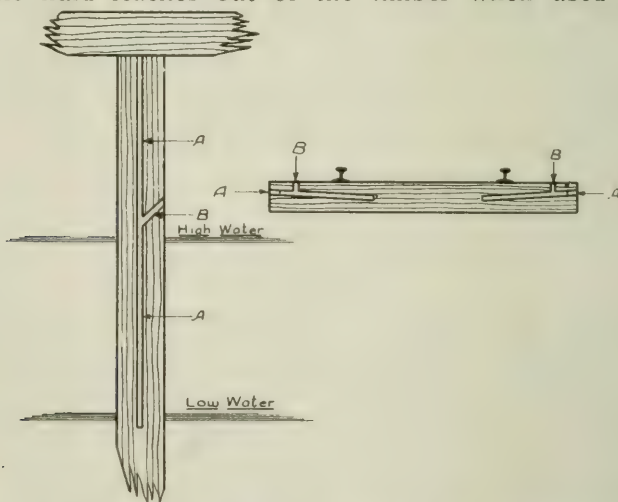
Blue prints of plants 1 and 3 are included in this report. It is clear that a low-pressure plant is much less costly than one equipped for high-pressure. Moreover, the former type of plant is less expensive to maintain and operate and is suitable for the application of a full-cell or empty-cell treatment."

I was rather amused, in the light of Mr. Hall's letter to me of last April (in which he said that the department was not attempting to compete with private individuals), to find that 60 days later he was offering to furnish free plans and specifications

for another plant; and also the services of an assistant to superintend the erection of the plant and instruct the parties in the operation thereof, for the munificent sum of \$75.00 per month. I am sure that people who want that class of service are welcome to it. I think the department has gone outside of its sphere, when it undertakes to furnish plans, specifications and superintendence on such work.

Mr. Wilson, in his letter to me, suggested that he was entirely willing to stop all work in these lines whenever it was demonstrated that private interests would take it up. I replied that we did not want the Forest Service to stop its work, for there is a tremendous amount of investigation and experimental work that needs to be done in timber preservation, and which only the government has the time and money to do. Let the Forest Service do this and leave the design and construction of plants to the individual. If there were not men in this country who were familiar with the construction and operation of timber-treating plants, I would most heartily say to the Forest Service, "Go ahead!" but it is a curious fact, notwithstanding all the effort that the department has put forth, it has not yet proposed one single improvement in a timber-treating plant. It has exploited the non-pressure method, which is good for an extraordinary situation and nowhere else; but this is not a new process by any means. There has not been a single improvement made in the treating of timber which has been originally recommended by the government

*Theodore Kandler, M. W. S. E.:* It has been said that the antiseptic fluid leaches out of the timber when used in wet



places. Has it ever been tried to replace the preservative fluid by means of holes in the timber to contain a fresh supply?

Suppose a pile in use, as illustrated; that part of the timber between high and low water decays first. Suppose there are holes provided which will permit the replacement of the preservative (leached out) by filling these with a fresh supply. Would the capillarity in the wood transfer the preservative outwardly from the central cavity? A plug would close the opening.

Suppose a railroad tie with holes bored in from the ends, and provided with plugs which will permit the introduction of the preservative. Would that be of practical value?

*Mr. Barnum:* I think perhaps that would work all right. An application for a patent involving the same principle has recently been sent to the department. It is to be used in connection with treating telephone poles in position. A hole is first bored in the pole and then a small receptacle, constructed of pipe, is attached. After the pipe is in position it is filled with creosote and allowed to remain. The preservative is then gradually taken into the wood by capillary attraction. At first there were to be three openings in the pole, 120° apart, and three connections leading to the main pipe. Afterwards one was found to be sufficient. A section of a pole treated in this way was sent to the department also. It showed a good penetration of creosote, of about 1½ in. The patentees claim they can get about 12 lb. of creosote into a pole. The scheme looks as if it might be practicable, but it has not yet been thoroughly tested.

*Mr. Kandeler:* How far above the ground would the treating be begun?

*Mr. Barnum:* About a foot to eighteen inches above the ground would be sufficient. In the South the whole pole must be treated. In this part of the country I think it is only necessary to treat the butt of the pole. It is claimed that good results are secured with this treatment.

*A Visitor:* That estimate of 9c a pole is very attractive.

*Mr. Barnum:* That is only a general approximation based on the average life of all poles in this country.

*Mr. Chanute:* By way of explanation I will state that the idea of boring a hole in a stick of timber, in order to introduce a preservative substance, is a very old and natural one, but it was found that the results were quite unsatisfactory, in consequence of the fact that the structure of the wood is such that the sap cells chiefly communicate lengthwise with each other, so that with a given piece of timber about three-quarters of the solution goes in through the ends and about one-quarter through the medullary rays. Now, the only way in which creosote, bottled up in a hole in timber, can saturate the rest of the wood is through the medullary rays, and that has been found inefficient.

*President Allen:* I will ask Mr. Barnum if he can give us a description of the non-pressure process.

*Mr. Barnum:* The non-pressure process has received the support of the Forest Service because it is believed to supply the need of the small consumer who cannot afford to go to the expense of putting in a large plant with its complicated equipment. Several of these plants have been erected in the South for treating short-leaf and loblolly pine. The preservative is forced into the wood by atmospheric pressure. The wood is run in an ordinary cylinder, the cylinder being made of very light— $\frac{1}{4}$  in.—iron, and then oil is admitted and heated up to 220 or 230 deg. F. This hot bath lasts from two to three hours and expels part of the air and moisture in the wood cells. The hot oil is then withdrawn from the cylinder and immediately replaced by cold oil. The charge of cold oil causes the expanded air to contract and a vacuum is formed which is destroyed by the entering oil forced in by the greater pressure of the atmosphere. Very good results have been secured in treating porous wood with this process, and it is comparatively easy to get the preservative all the way through loblolly and short-leaf pine—clear up to the heart. Good results have also been secured in treating red oak ties by the non-pressure process, but the red oak is more difficult to treat than pine. Of course, the non-pressure process can by no means take the place of the pressure process. It is simply advantageous for the treatment of very porous wood, where the amount of money available for the construction of a plant is comparatively small.

*Mr. Chanute:* I will say that if that process can inject an average of 12 lb. of solution to the cubic foot, we do not need anything better.

*Mr. Curtis:* In the treatment by the ordinary pressure process, one does not depend upon first heating the wood and then chilling it by the cold oil to produce the vacuum. This is done much better by a vacuum pump and then supplementing the atmospheric pressure by pump pressure. I have never got too much oil penetration in the ties, even with a 24-in. vacuum and 150 lb. pressure. I have never seen an oak tie in which I could get that degree of penetration which I think we ought to have. I do not know that I have ever treated loblolly pine ties by the full-cell process, but I have treated a great many thousand such ties by the Rueping process. With that process we first produce in the cylinder 50 lb. air pressure, and then run in the oil and put on 150 lb. of oil pressure. If the loblolly pine ties have been well seasoned, on cutting a tie in the middle it will be found treated right down to the heart, although not all the way through as a rule. It is difficult to get the solution into the heart, which, of course, will vary somewhat in size, but ordinarily it will come down to a  $1\frac{1}{2}$  to 2 in. ring. In other words, it was as fine a treatment as one could expect to get.

In regard to oak and some of the other hard woods, I have

never been able to get uniform results. Investigation will show good treatment in one instance, while in another instance the treatment would be superficial. I do not doubt that Mr. Barnum has been able to get good results with sap-wood and loblolly pine when well seasoned. But unfortunately in the timber-treating business one wants to get uniformly good results. Of course, absolutely uniform results cannot be obtained by any process, but we are aiming to reduce the percentage of poor results. I remember that Mr. Chanute became discouraged at one time with tamarack wood because he could not get absolutely uniform results. I am in some doubt as to the results which we are going to find in this country 10 years from now, with the oak ties we are treating with oil today. Some of the results which have been secured in oak, in this country, with the zinc chloride process, have been remarkably good, and some much better than I was ever sanguine enough to anticipate. I think the first year that the Carbondale plant was run it treated a lot of red-oak ties for southern Illinois, where the rainfall was about sixty inches, and the last report I had was that those ties showed up remarkably well. However, I should never anticipate very great results from red-oak ties laid in that territory. There is a good deal of clay there, which is a great water holder. The rainfall, too, is very heavy.

The results from treating timber with zinc chloride have been remarkably satisfactory.

I believe that there are many things to be learned about timber, and about treating it, and I am hoping that Mr. Barnum will teach us how to secure those uniformly good results that we are all looking for. I have tested a great many sticks and have been surprised and disgusted by the failure to get results. This summer it was necessary to treat a lot of long-leaf yellow pine soon after it was sawed. It was given a much longer treatment and more steaming than usual. The steaming was continued for six hours at a reasonably high pressure—the oil pressure was 165 lb. The work was done in a plant where I know the treatment was absolutely conscientious, yet on sawing some of those sticks in the middle, the results were very disappointing. I reached the conclusion that if I had any more timber to treat fresh-sawed, it must be loblolly pine, as long-leaf pine is not fit to be so treated. The vast difference between the penetrability of timber to a water solution and to oil is a curious thing.

*Mr. Barnum:* The Pennsylvania Railroad Co. has recently built a new plant, where they are treating red-oak wood and are getting a thorough penetration. The ordinary oil pressure treatment is given, after which an air pressure of 100 lb. per sq. in. is placed on the timber. This air pressure is held for about half an hour. When the air pressure is released a vacuum is

drawn and held for the same period. The air pressure and vacuum diffuse the oil entirely through the wood in a uniform manner.

*President Allen:* I recently saw some samples of timber treated by a process applying a pressure at one end of the stick, with a vacuum at the other end. Can anyone tell us about that process?

*Mr. Curtis:* It is only a modification of the old Boucherie process. There are other methods similar to that you mention, excepting in minor details. There is no virtue in the vacuum; it exists only through absence of pressure, and an increase of pressure at the other end amounts to the same thing.

*L. J. Hotchkiss, M. W. S. E.:* I should like to ask if Douglas fir takes treatment satisfactorily. We are using a great deal of this timber and I have been told that it cannot be successfully treated. If anyone here has tried to do it, I wish he would tell us what his experience has been.

I should also like to ask as to the relative merits of treating timber which has been air-seasoned, and of taking it green and steaming it as a part of the treating process. Not long ago I was talking with a man who is in the business of treating timber, and he advocated steaming it. His idea is that the life of a stick of timber is only a certain number of years and if it is air-seasoned before treating, the time required for this seasoning is just so much of its useful life lost. He thinks if it is steamed instead, this loss is avoided with no injury to the timber to offset it. I should like to know the opinion of others on this point.

*Mr. Chanute:* In regard to Mr. Hotchkiss' second inquiry, with reference to steaming. We have tried several hundred experiments in order to determine the advantage or disadvantage of steaming, and found that, in order to extract the sap, it was necessary to have some motive power. If the wood was partly seasoned the sap has evaporated to a good degree and air has flown into the sap cells. Now, by steaming, the air is heated and drives the sap out of the cells. If the timber is fresh cut and full of sap you have got to apply sufficient heat to the center of the tie to generate steam—or a heat of 212 deg.—in order to drive out the sap and replace the action of the heated air. We took ties and steamed them one, three, five, six, seven, and twelve hours. We bored holes in them, which we plugged up, and after the tie came out we removed the plug and inserted a thermometer, to ascertain what the temperature was. We found we got a temperature of 212 deg. F. with not less than 8 hours steaming.

In creosoting piles in the South, I understand in some cases they are steamed 24 hours before the sap can be extracted and the creosote put in.

With respect to the first question asked by Mr. Hotchkiss, as to whether Douglas fir takes treatment satisfactorily or not, I may say that the Southern Pacific R. R. Co. claim they treat it better when it is fresh cut than after it is seasoned, and all the ties which they are treating are treated fresh cut. I thought the statement extraordinary, and went out to California to investigate the matter. I found that the information was correct,—that the Douglas fir, fresh cut, was more easily treated (by steaming) than when seasoned, the reason being that the Douglas fir contains a good deal of resin. That resin is fluid when the wood is fresh cut, but after the wood has been cut for a while the resin gums in the cells and resists the injection of the solution.

*Mr. Curtis:* I simply want to supplement what Mr. Chanute has said. If Mr. Hotchkiss refers to the treatment of timber with oil, the proposition is somewhat different. I have never had an opportunity to treat Douglas fir, but believe it cannot be done by the ordinary pressure method. The only way I know of to treat Douglas fir timber satisfactorily with oil is by boiling it in the oil and supplementing by pressure. In that way a penetration is obtained which is satisfactory.

*C. F. Loweth, M. W. S. E.:* Referring to Mr. Hotchkiss' question about the treating of Douglas fir, I will say that about a year or so ago we contracted with a reputable and experienced wood-treating plant to treat a lot of Douglas fir timber. The company assured us that although they had not been treating Douglas fir, they were confident they knew how to do it. They made an energetic, and I believe an honest effort, but the result was a failure. The timbers to be treated were the ordinary pilebridge stringers, 8x16 in. in section by 32 ft. in length; they had been lying in a yard for a couple of years or more and were thoroughly seasoned. Notwithstanding the efforts of the firm to treat this timber, it appeared impossible to force the creosote in at the sides and rarely was the penetration as much as  $\frac{1}{8}$  in. in depth; but it was quite easy to force the creosote into the ends of the timbers, and in some cases at a distance of 8 ft. from the ends, as I remember it, about half of the section of the timber would be saturated and doubtless the penetration from the ends extended a very considerable distance. This left the skin or surface, of the stick with a very imperfect and inadequate protection, because a very slight season-check would open up a portion of the interior which had received no treatment. The people made many efforts, experimenting one way and then another, and in several cases the timbers were very badly distorted by the unequal heating, etc. I am inclined to think that fir timber can best be treated while green and by what is known as the boiling treatment.

Those same people at that time had another unexpected

experience. Their order included some 8x8 in. 12 ft. long Minnesota white pine bridge ties. White pine is very rare nowadays, at least for such purposes. It was generally supposed that this material would take treatment as easily as loblolly pine; but this was soon discovered to be a mistake, for the ties did not take the treatment, and what was more surprising, the contractors were not able to find out how to get the creosote into the timber. The best that could be done seemed little better than what might have been obtained by merely soaking the timber in a bath of creosote. I turned some of the samples over to Mr. Curtis who took them to one of his treating-plants and tried his method or methods, but I dare not mention the results. The white pine ties were freshly cut and full of sap and frost.

*Mr. Curtis:* Mr. Loweth sent to me, at my request, four samples 8 in. by 8 in., 6 ft. long, as pretty samples of white pine as I have ever seen. I expected to fill them so full of oil that they would be dripping for six months. I put one piece in the cylinder with a run of piling, and after taking it out and cutting it I was ashamed to show it to Mr. Loweth. I tried another sample by the Rueping process, and curiously enough (though we did not have the same oil pressure by 50 lb. as we did on the first trial) on that sample we got a good treatment. Other tests by the same method, however, were unsatisfactory.

When one gets into the subject of timber, no matter how expert he may be he is going to have some surprises. I would not have believed that I could have any difficulty in treating white pine. I believe that it can be done, but I will admit that I do not now know how.

*Mr. Barnum:* The Forest Service is anxious to work in co-operation with engineers and hopes to be of use to them in helping solve those problems which have to do with the nature and uses of timber.

## LOW TENSION FEEDER SYSTEMS FOR STREET RAILWAYS.

R. H. Rice, M. W. S. E.

*Presented at a Joint Meeting W. S. E. and A. I. E. E.,  
December 22, 1909.*

An electrical distribution system in general is made up of a network of conductors which convey the electrical energy from its points of generation to the locations at which it is to be utilized. The distributing lines for a street railway system constitute a special and relatively simple case of such a network. Its component parts are:

1. The contact conductor, or trolley wire, from which the car receives its current.
2. The conductors, or feeders, from the power house or substation switchboard which deliver current to the trolley wire.
3. The returns, or conductors, which complete the electrical circuit from the car to the power station.

It is the purpose of this paper to explain the methods used in calculating the feeders and to show the general results obtained on the street railway systems of Chicago, which come under the jurisdiction of the Board of Supervising Engineers.

There are four companies with 687 miles of single track operated, and a total of fifteen power stations, aggregating 95,150 kw. rated capacity. The calculations for feeders were made upon a basis of 2,264 double truck cars, or their equivalent, which were required to operate the proposed schedule.

On the lines of these companies but two steam power houses are in operation. In all other cases power is purchased and is transmitted at 9,000 volts, three phase, to the various substations and there transformed to direct current. All of these substations have been very recently built and are of the most approved construction throughout. At present the direct current bus voltage is run somewhat lower than 600 volts, but it is intended to raise it to this value, after low voltage motors have been eliminated and other necessary changes have been made.

The trolley wire on all streets is sectionalized by inserting section insulators at various points, and each of these trolley sections has a feeder consisting of one or more cables extending from the section to the power station most convenient to it. The choice of locations for these section insulators is largely dependent upon operating conditions, and also upon the location of a section with reference to the power station.

To determine the actual power requirements for the type of double truck car now used in Chicago, a series of fifteen tests were made on a car which was operated in regular service for

three days. This car was equipped with ammeters, voltmeters, a recording watt-hour meter, and a speed recorder. A careful log was kept of its operation under all the varying conditions of service on different lines and at different periods of the day.

In addition to the above individual car tests, several section tests were undertaken. These consisted in determining the number of cars on a chosen trolley section by observing the times of entrance and exit of cars from the section and during the period of the test, noting the ammeter and voltmeter readings at the station switchboard. The chosen sections were of several miles in length and the traffic over them was quite heavy. All tests were run between 12 m. and 8 p. m. From the results of these tests the power requirements for a car under various conditions were determined and used in the feeder calculations.

Some study was also given to the safe carrying capacity of cables, and as a large portion of the territory covered by the feeder system is designated as underground territory by the ordinances under which the railway companies are operating, it was necessary to consider lead sheathed, as well as weather-proof overhead cables. Owing to the presence of various tunnels, low subways under railroad tracks, and some low level duct lines, it was considered desirable to use rubber insulated cables in these places and paper insulated cables elsewhere.

A question of considerable importance is the interconnection of stations so that the temporary shutdown of one will not throw out of service all the sections fed from that station. One method of accomplishing this, would be to install into every station sufficient copper leading from the adjacent stations to enable the full-current capacity of the disabled station to be fed into it from the others. The presence of such trunk tie lines would be highly desirable during an emergency, but would be of no service at other times, except as equalizers between the stations. The investment necessary for such ties would be quite large, and essentially the same results may be secured by selecting a certain number of the more important trolley sections and feeding them from two stations. The feeders to these sections are so proportioned and calculated, that on the whole system in case of the shut-down of one or two stations, a certain proportion of the cars can be carried on the remaining stations by interconnecting through these tie lines.

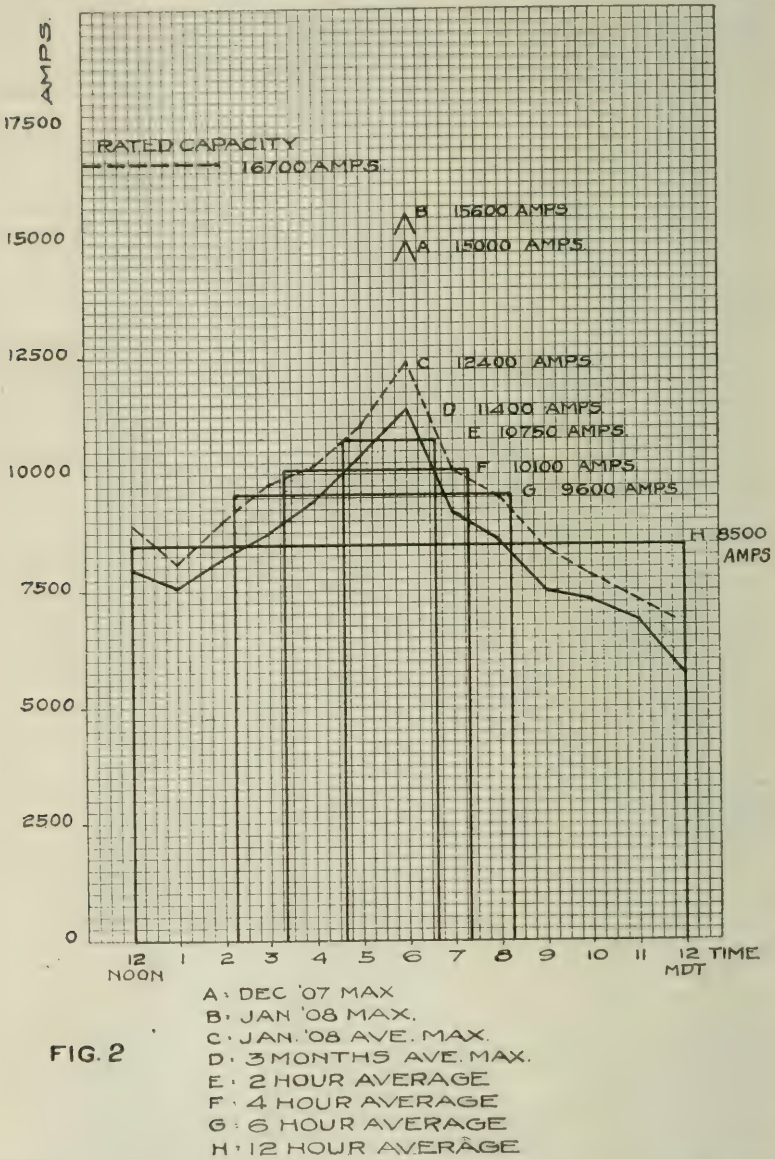
On any individual trolley section, in case of the shut-down of one station, or of accident to one feeder, the cars on the section could still be operated from the other station by means of the second feeder.

The illustration, Fig. 1, shows the station capacity of one system in amperes, for operation at 600 volts. Local conditions and the situation of the stations determine the tie capacity between any two of them. In the system here shown the stations



watt hours to the actual load as it exists on the station for the twelve-hour period shown.

If the feeder system is designed to carry the peak loads, such



as *A* and *B*, without an overload on the cables, then during a large part of the day the current in the cables will be far below

their safe carrying capacity and considerable copper will be idle. On the other hand, if the feeder system should be designed on a basis of say a six-hour average, as shown by curve *G*, then the cables would be subjected to large overloads for a considerable period of time, heating would occur, the cables would more rapidly deteriorate, and a shorter life would result.

It was decided to use the two-hour average as a basis for all calculations, in this case represented by curve *E*. This means that the feeder systems are so designed that they will carry the entire load without being overloaded, except during a two-hour morning and evening peak. The ordinary percentage of excess load is well within the overload capacity of the cable—that is, the current it will carry for this short period without undue heating.

From the preliminary studies and tests made by the Board of Supervising Engineers, as previously outlined, the basis for all feeder calculations was formulated and established by resolution. This basis may be itemized as follows:

- 1st.—The direct-current bus bar at power houses or sub-stations will be operated at approximately 600 volts.
- 2d.—An allowance of 40 kw. in power house or sub-station capacity for each standard double-truck car of the type approved by the Board of Supervising Engineers, weighing approximately 26 tons, light, or its equivalent, will be provided at each direct-current bus bar.
- 3d.—In calculating the copper for current-carrying capacity an allowance of 75 amperes for each standard double-truck car, as described above, or its equivalent, shall be allowed.
- 4th.—An average drop of 50 volts will be allowed between the D. C. bus bars and the center of gravity of the trolley section, due provision being made for suitable tie lines to take care of emergency cases.
- 5th.—The carrying capacity in amperes of insulated lead-covered underground cables and of overhead weather-proof cables shall be calculated upon the following basis:

		Lead Covered		Triple Braided
		Rubber	Paper	Weatherproof
1,000,000	C.M. Cable	.....800	1000	1250
500,000	“ “	.....500	600	625
350,000	“ “	.....375	425	450
4/0	“ “	.....	...	325

The general method adopted in feeder calculations may be illustrated by the successive steps used in one particular system, the detail of calculation being shown later.

1. From the proposed schedules, the number of cars which

will be operated on each route during the rush hours is determined. The cars are distributed and plotted upon a skeleton map of the system which is called a *Spot Map* or car distribution map; Fig. 3. The afternoon maximum period is usually the heaviest service period, so that the car distribution for two hours of what is styled the *P. M. Rush* is used on this map.

2. The trolley sections, as previously determined, are then drawn, and the number of cars on each are multiplied by 75, which gives the total average maximum load for each individual trolley section in amperes. This amount is placed in a small circle at the center of gravity of the trolley section, and the map is known as the trolley section or load distribution map, as shown in Fig. 4.

3. A study is then made of the proper location of power stations. The best probable locations are selected, and a calculation of station load centers is made by finding the combined center of gravity of the loads about a given station, as indicated in Fig. 5. This center of gravity of the loads is determined by the well-known process in mechanics, in this case the number of amperes on each section taking the place of the number of pounds weight. In the case of tie sections, the load is divided between two stations in amounts which may readily be calculated, as shown later. The section is thus virtually divided into two sub-sections of such lengths that the load on one sub-section is carried by one station and the load on the other is carried by the second station. The dotted circles represent the centers of load of these sub-sections, and the numbers within them the portion of the total load on the sub-section.

If a given system is to be fed by a single power house, the system load center is also determined, which will show the most economical location, so far as distribution copper is concerned, for the generating station. If the locations chosen are not the most economical for distribution copper, studies are made of comparative costs for other locations where the company may have property or where real estate for sub-station purposes may be obtained to advantage.

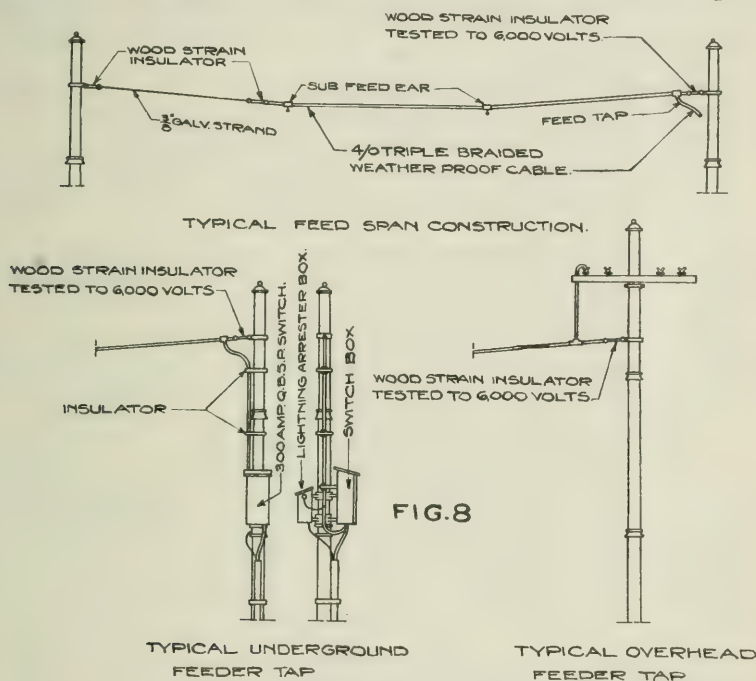
4. After the station locations are definitely settled, and the sections which are to be fed from each station are decided upon, a *Spider Diagram* is added to the trolley section map, which now becomes a drawing of record and shows at a glance what sections are fed from any given station, and what average maximum load is to be expected upon that section. This is illustrated in Fig. 4.

5. A study is then made of the feeder routes, and having determined them, a *Feeder Diagram* is prepared which shows the route and number of each cable from the power station to the section load center, as shown in Fig. 6.

6. If the feeders are to be placed underground, it is neces-

sary to lay out conduit lines. A diagram, Fig. 7, is used for this, the number of cables over a given section being represented arbitrarily by the numerator of a fraction, and the number of ducts by the denominator. Extra ducts are provided in all conduit lines where practicable, to provide for future growth without tearing up pavements. The percentage of extra ducts will vary for different locations, depending upon the estimates of future requirements.

A typical feeder tap is illustrated in Fig. 8, which shows the lead-covered cable rising up the pole and passing into the switch box. From this point weatherproof cable is used, passing up-



ward and being connected to the feeder span which replaces the galvanized strand wire used on other spans. An overhead feeder tap is also shown on the same drawing.

The calculation of feeders may be conveniently based upon two theorems in addition to Ohm's law:

1. The maximum drop, measured from one end of a uniformly loaded conductor, is one-half the drop produced by an equal load concentrated at the distant end. Or stated in another way, the maximum drop on a uniformly loaded conductor is equal to the drop produced by the total load concentrated at the center of the conductor.

2. This theorem has to do with the mathematical similarity

between moments in a mechanical system and drops in an electrical system. For example, a beam supported at both ends and having on it a certain distribution of load will be in equilibrium when the sum of the moments about any point on the beam is zero. Similarly, if a conductor has current fed into it from both ends to supply any distribution of load upon it, there will be for every distribution some point of division on the conductor through which no current flows. This is the point of maximum drop, and of equal drops from both ends, and the system may then be said to be in equilibrium. In the electrical system we have current, resistance, and drop, corresponding respectively with load, distance, and moment of the mechanical system. If the conductor is of uniform size, we may use length of conductor instead of resistance.

In making the detailed calculations for the various trolley sections, two types of sections are to be distinguished:

A. *Isolated*; those receiving power from one station only.

B. *Tie*; those receiving power from two stations.

The fundamental assumptions underlying all these calculations are:

1. All stations operating at the same voltage. If this is not the case, a simple modification may be made in the calculation to properly provide for the difference.

2. The load on each trolley section is uniformly distributed, and feeder taps at approximately equal intervals reduce the load uniformly. This is a condition which is approximately true in city systems operating on a short headway.

3. No account is taken of the conductivity of the trolley wires which are in parallel with the feeder for a portion of its length. In any ordinary case, the trolley wires form such a small part of the total copper required for a section that their neglect introduces small variation in the results of calculation.

Most, or perhaps all, of the above assumptions would be modified in calculations involving an interurban road or a small city system.

In the case of an isolated section, such as shown in *M*, Fig. 10, the calculation is very simple. The section *AB* of length *L* feet has a uniformly distributed load of *I* amperes, which is considered concentrated at the center of the section. If *r* is the resistance per foot of feeder, the drop from the power station to the nearer end of the section is  $r D I$ . The added drop to the end of the section is  $\frac{1}{2} r L I$ , if the feeder is continued undiminished in size to the end of the section. The total drop is

as given by the equation  $E = r \left( D + \frac{L}{2} \right) I$ . (1) If the feeder is

reduced in size as the load decreases, the maximum drop at the end of the section will be somewhat greater than that given.

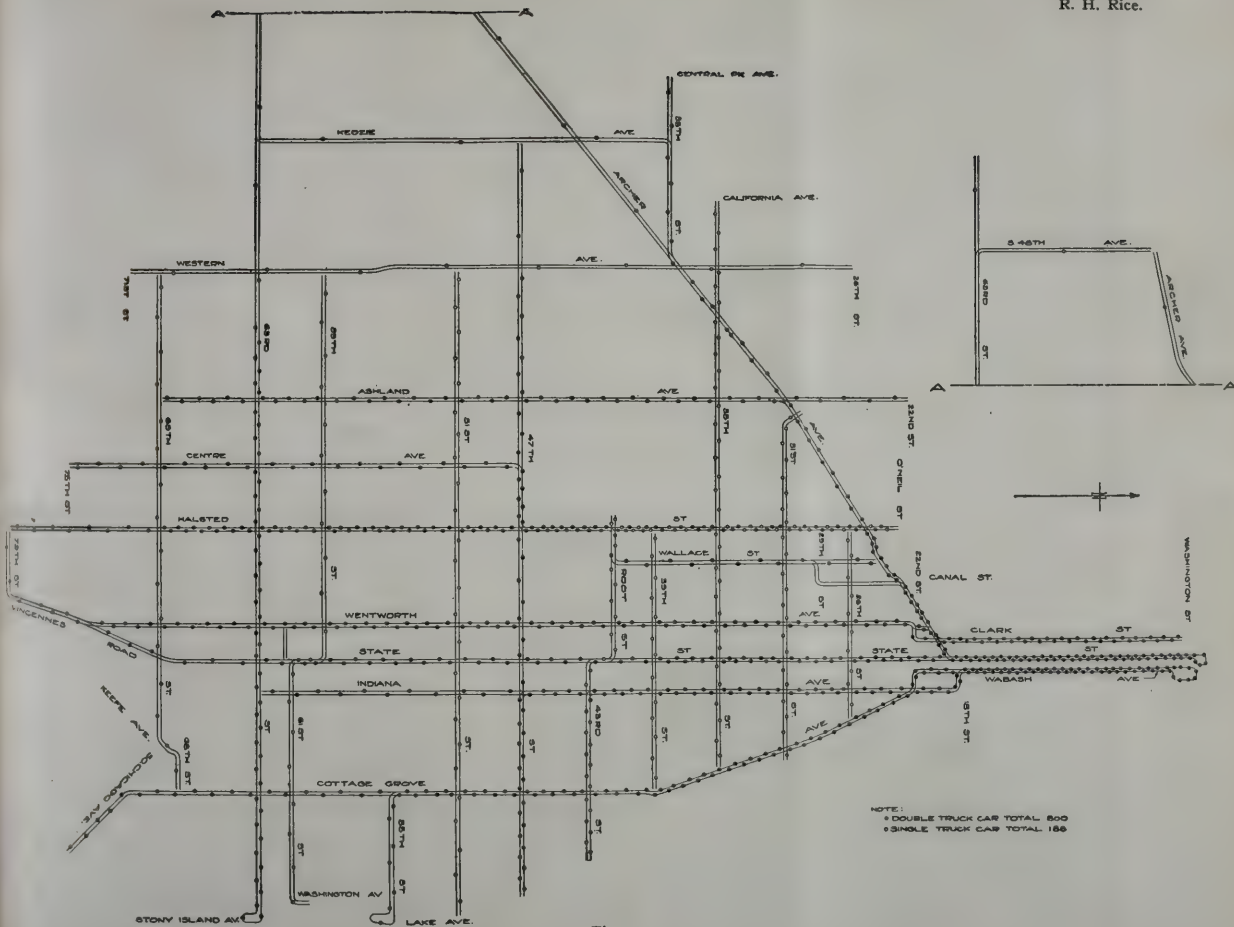


Fig. 3.



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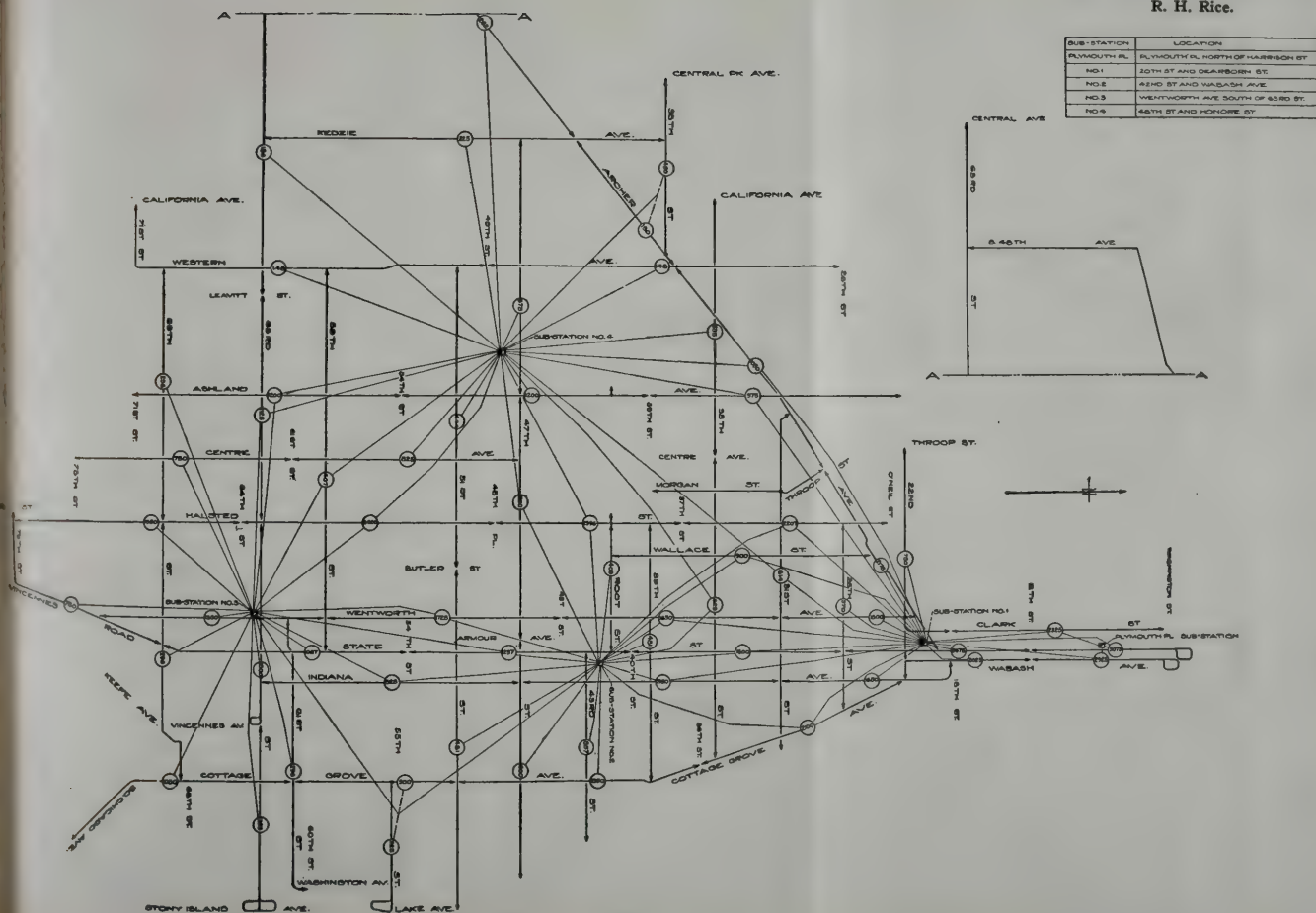
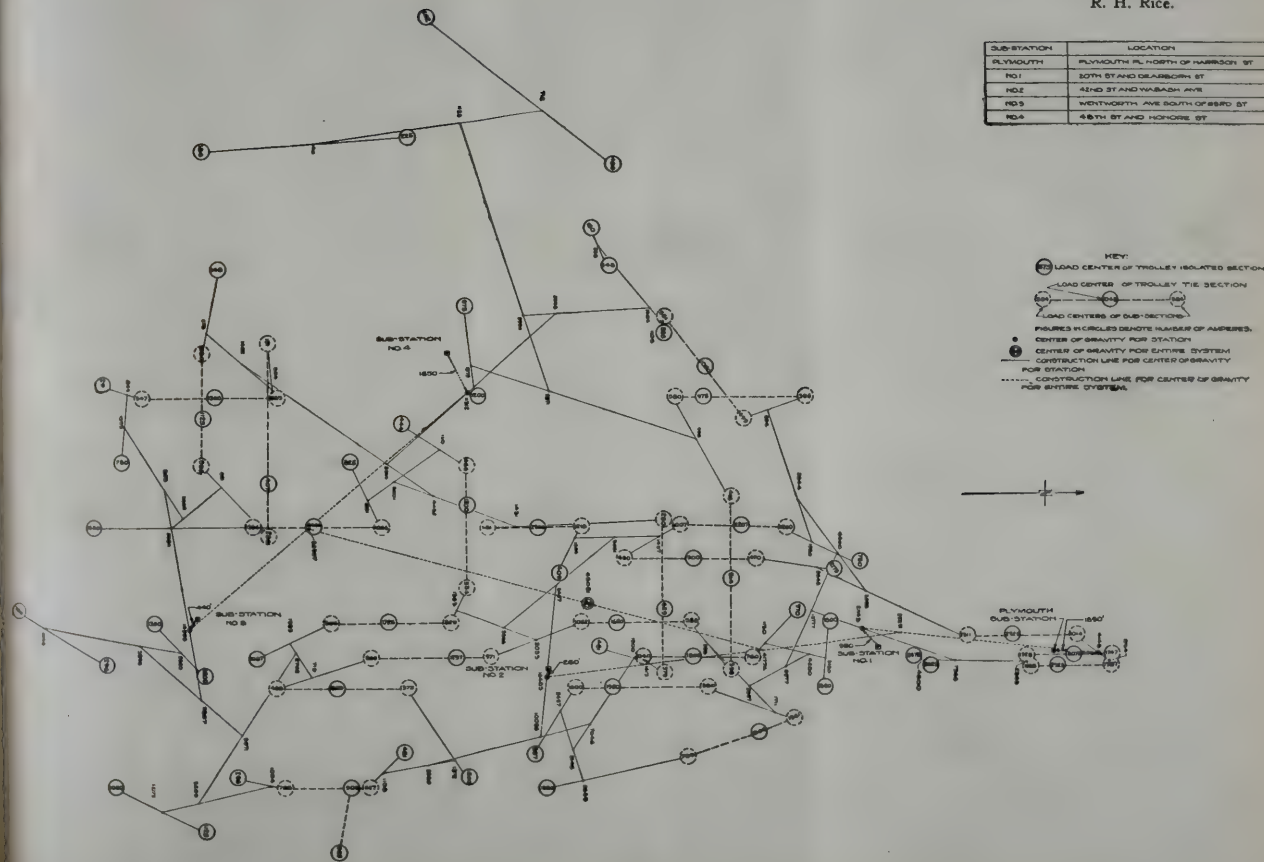


Fig. 4.



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SUB-STATION	LOCATION
PLYMOUTH	PLYMOUTH PL. NORTH OF HARRISON ST.
NO. 1	20TH ST AND DEARBORN ST.
NO. 2	42ND ST AND WISCONSIN AVE.
NO. 3	THIRTIETH AVE. SOUTH OF 55RD. ST.
NO. 4	48TH ST AND HONORE ST.





BUS STATION	LOCATION
PLYMOUTH	PLYMOUTH RD. NORTH OF HARRISON ST
NO. 1	20TH ST AND DEARBORN ST
NO. 2	42ND ST AND WABASH AVE.
NO. 3	WENTWORTH AVE. SOUTH OF 68TH ST
NO. 4	45TH ST AND MONROE ST.





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SUB-STATION	LOCATION
PLYMOUTH	PLYMOUTH BLVD. N. OF HARRISON ST.
NO. 1	BOTH ST. AND DEARBORN ST.
NO. 2	42ND ST. AND WABASH AVE.
NO. 3	WENTWORTH AVE. SOUTH OF 65TH ST.
NO. 4	46TH AND HONORE STS.

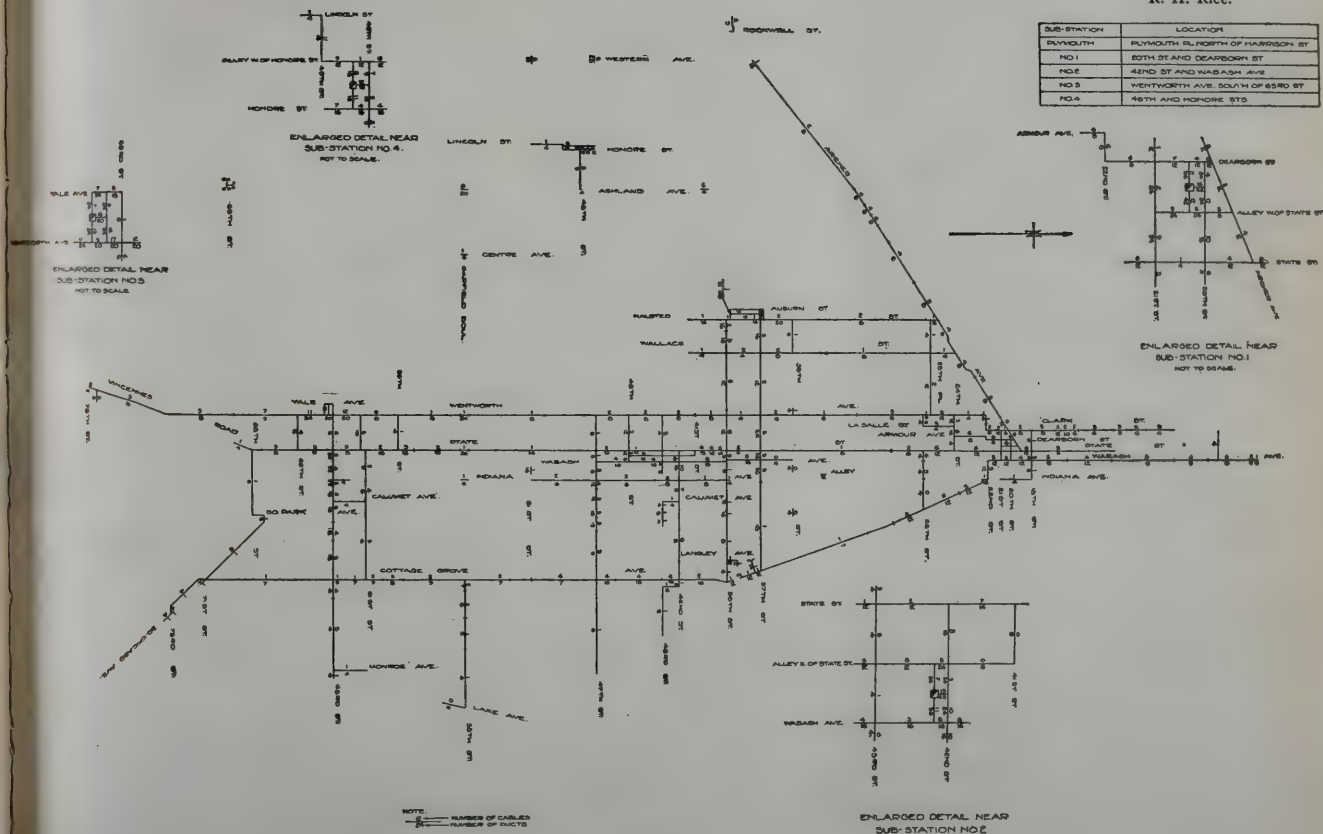
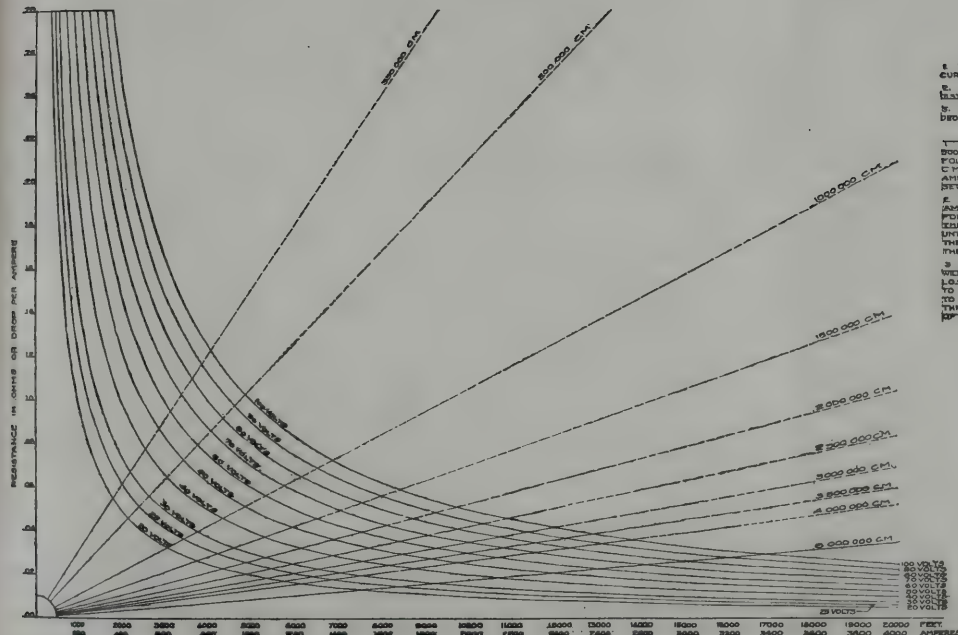


Fig. 7.

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USE OF CURVES.

1. TO FIND THE DROP WHEN THE DISTANCE, CURRENT AND CIRCULAR MILS ARE GIVEN.
2. TO FIND THE CIRCULAR MILS WHEN THE DISTANCE, CURRENT AND DROP ARE GIVEN.
3. TO FIND THE DISTANCE WHEN THE CURRENT DROP AND CIRCULAR MILS ARE GIVEN.

EXAMPLES

1. FIND THE DROP ON A 3,000,000 C.M. CABLE, 8000 FEET LONG AND CARRYING 400 AMPERES. FOLLOW 5000 FOOT ORDINATE UP TO 3,000,000 C.M. LINE, THEN HORIZONTALLY UNTIL 400 AMPERE ORDINATE IS CROSSED. THIS INTERSECTION AT 47% GIVES THE VOLTS DROP.
2. FIND THE CIRCULAR MILS TO CARRY 800 AMPERES, 8000 FEET WITH 30 VOLTS LOSS. FOLLOW THE 800 AMPERE ORDINATE UP TO 30% VOLT LINE, THEN HORIZONTALLY UNTIL THE 8000 FOOT ORDINATE IS CROSSED. THE LOCATION OF THIS INTERSECTION GIVES THE SIZE AS 2,500,000 CIRCULAR MILS.
3. FIND THE DISTANCE A 1,000,000 C.M. CABLE WILL CARRY 800 AMPERES WITH A 40 VOLT LOSS. FOLLOW THE 800 AMPERE ORDINATE TO THE 40 VOLT CURVE, THEN HORIZONTALLY THROUGH THIS LINE GIVES THE DISTANCE AS 9350 FEET.

C.M.	RES. PER 1000 FEET
350,000	030204
500,000	021192
1,000,000	010580
1,500,000	007041
2,000,000	005240
3,000,000	003664
4,000,000	002800
5,000,000	002307
6,000,000	001960
7,000,000	001700

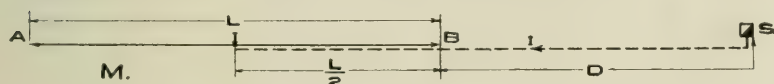
RADIAL RES. OF 1000 FEET OF 1000,000 C.M. = .0108 OHMS (98% COPPER)

NOTE: SOLID PORTIONS OF RADIAL LINES INDICATE RANGE OF CURRENT CAPACITY

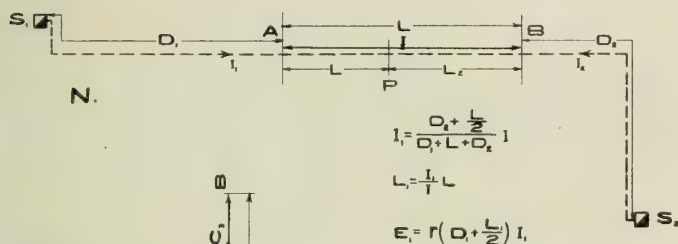
Fig. 9.

The calculation of a tie section is a little more complex. Take, for instance, the simplest case, illustrated by *N* in Fig. 10, in which the main feeder between stations is assumed to extend the entire length of the section and to be uniform in size. The section *AB* has a uniformly distributed load of total value *I* amperes, of which *I*<sub>1</sub> amperes are assumed to come from station *S*<sub>1</sub> and *I*<sub>2</sub> amperes from *S*<sub>2</sub>. *P* is the point of division of load between the stations, and is the point of maximum drop on the

## TYPICAL TROLLEY SECTIONS



$$E = r(D + \frac{L}{2}) I$$



$$I_1 = \frac{D_1 + \frac{L}{2}}{D_1 + L + D_2} I$$

$$L_1 = \frac{I_1}{I} L$$

$$E_1 = r(D_1 + \frac{L_1}{2}) I_1$$

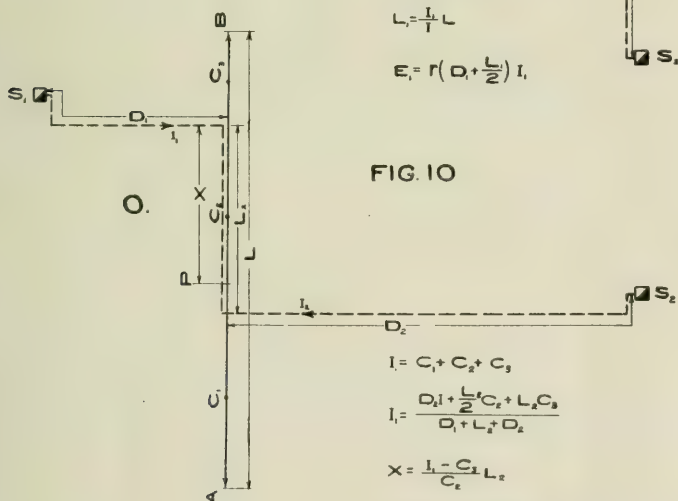


FIG. 10

$$I = C_1 + C_2 + C_3$$

$$I_1 = \frac{D_1 I + \frac{L_1}{2} C_2 + L_2 C_3}{D_1 + L_1 + D_2}$$

$$X = \frac{I_1 - C_1}{C_2} L_2$$

$$E = (I_1 - C_1) \frac{rX}{2} + I_1 D_1$$

section. We are usually concerned in knowing the load on each station and the maximum drop on the section.

To determine the load *I*<sub>1</sub> on station *S*<sub>1</sub>, take moments about

$S_2$ . These moments must be so chosen that they will involve only the one unknown whose value is sought, otherwise the solution of simultaneous equations becomes necessary, and much needless labor is introduced. In this case assume the total load concentrated at the center of the section; then its moment about  $S_2$  would be:

$$(D_2 + \frac{L}{2}) I$$

The moment of the load  $I_1$  at  $S_1$ , which would just balance this moment about  $S_2$ , is:

$$(D_1 + L + D_2) I_1$$

Equating and solving, we get the load on  $S_1$  equal to

$$I_1 = \frac{D_2 + \frac{L}{2}}{D_1 + L + D_2} I \quad (2)$$

which shows that the load on one station is equal to the total section load, multiplied by a fraction whose numerator is the distance from the second station to the center of the trolley section, and whose denominator is the distance between the stations.

The location of the point of division of load is readily determined. Since the load is uniformly distributed, we get

$$L_1 = \frac{I_1}{I} L \quad (3).$$

The maximum drop occurs at  $P$  and is

$$E_1 = r (D_1 + \frac{L_1}{2}) I_1 \quad (4).$$

A second type of tie section is one in which the main feeder between stations does not parallel the trolley section throughout its length, as shown at  $O$ , in Fig. 10. The loads on the three parts of the trolley section are  $C_1$ ,  $C_2$ , and  $C_3$ . We then have:

$$I = C_1 + C_2 + C_3 \quad (5).$$

To find the load on  $S_1$  we take moments as before about  $S_2$ , which gives:

$$C_1 D_2 + C_2 (D_2 + \frac{L_2}{2}) + C_3 (D_2 + L_2) = I_1 (D_1 + L_2 + D_2).$$

Multiplying out and factoring, we get:

$$(C_1 + C_2 + C_3) D_2 + C_2 \frac{L_2}{2} + C_3 L_2 = I_1 (D_1 + L_2 + D_2),$$

which, by use of (5) reduces to:

$$ID_2 + C_2 \frac{L_2}{2} + C_3 L_2 = I_1 (D_1 + L_2 + D_2),$$

and hence

$$I_1 = \frac{ID_2 + C_2 \frac{L_2}{2} + C_3 L_2}{D_1 + L_2 + D_2} \quad (6).$$

The load distributed over the distance  $X$  is  $I_1 - C_3$ , and since the distribution is uniform, we have

$$X = \frac{I_1 - C_3}{C_2} L_2 \quad (7).$$

The drop from  $S_1$  to the point of division  $P$  is then

$$E_1 = (I_1 - C_3) \frac{r X}{2} + I_1 D_1 r \quad (8)$$

which is the maximum drop on the feeder, but which may be exceeded at the ends  $A$  and  $B$  of the trolley section.

As an aid in making calculations in these and similar cases, there was prepared a series of curves as shown in Fig. 9. The radial lines represent the relation between lengths and resistances for various sizes of cables. The other set are curves of equal drops, and show the product of various resistances and currents. There are five elements entering into the curves: circular mils, current, drop, distance and resistance, and the curves are so related that the desired quantity may be read directly from the chart when the other values are known.

The method as given here has been found to be very satisfactory in practice. The results are obtained without any "cut and try" process, and by a little familiarity with the method, it is possible to work quite rapidly. The final results show those facts which it is usually necessary to know, viz., the division of load between stations and the maximum drop on the cable.

#### DISCUSSION.

*Mr. D. W. Roper, M. W. S. E.:* As the speaker was reading the carrying capacity of the several sizes of lead-covered cables, I wondered how the maximum carrying capacity of the cable

was determined; for instance, for rubber insulated 1,000,000 c.m. lead-covered cable, the maximum capacity was given as 800 amperes; does not that mean 800 amperes steady load, and is this load supposed to last for one hour or two hours corresponding to the peak of the load of the Railway Co., or in what manner is it determined?

I am interested in those figures, because we run our single-conductor paper insulated cables of the same size at a load at least 20% higher without any apparent injury. After the cables had operated such loads for a month or two we carefully examined them in order to see how badly they had been injured. We cut sections out of the cable at two locations and tested them in the laboratory. These tests indicated that the cable was apparently just as good as new. Somewhat later we had occasion to run another cable at a load even greater. In this case the lead sleeves covering the joints of the cable had collapsed, due to the paraffine filling of the sleeves having melted and run into the cable. This load was considerably beyond the figures given by the speaker, and aside from these sleeves covering the joints, there was apparently no injury to the cable. I am therefore wondering whether the limits as given in the paper were determined by theoretical considerations of the rise in temperature of the time, or by practical considerations.

*Mr. Rice:* The cable-carrying capacity was determined by a process of elimination and comparison. The safe current-carrying capacity, or what was considered safe current-carrying capacity, by various authorities was found and, taken in connection with the probable life of the cable, was put on a safe conservative basis. These figures were arrived at in that way, not directly as the result of a test or directly as the result of any complex theory. It was simply the judgment as to what was a safe, conservative figure. The load, as given, is for continuous current capacity.

*Prof. Woodworth, M. W. S. E., Chairman:* I judge, then, from Mr. Roper's remarks, that if a cable were carried very much beyond that safe load capacity for any length of time, the probability is, the cable would break down. The factor of safety is quite close.

*Mr. Roper:* I might add that the load we carried on the cables would, I imagine, result in only a slightly increased heating over what Mr. Rice figures here as continuous loads. I had, in making my remarks, assumed that they were taken for a load corresponding to the load curve we were shown for the railways. But if the capacity of the paper-insulated cable is taken as 1,000 amperes continuous, that would probably be within 10% of the capacity to which I referred as having been such as to cause disturbances to the joints and other mechanical troubles with the cable sheath. I should think if that were 1,000 am-

peres continuous, it would be pretty close to the ultimate safe capacity of the cable.

*Mr. E. N. Lake, M. W. S. E.:* I was thinking, while Mr. Rice was talking, that it was not so very long ago, perhaps two years, that Mr. Rice complained of not being able to find any particular literature on the subject of distribution systems for large street railway systems. I am sure you will all agree with me that he has produced, as evidenced here tonight, some very good literature upon this subject.

I had four or five items that I thought I might discuss, but I see that he has covered all of them except possibly one, which I think, out of the kindness of his heart, he left perhaps, just for my use, and that is one that might be of some interest. I will simply call your attention to it. It is this: Based upon 1,000,000 circular mil lead-sheathed cable, with the assumed load of 800 amperes maximum, and the limit of drop established as 50 volts, 6,000 feet approximately is the point to which carrying capacity governs. Beyond that point it is a matter of drop, so that theoretically the ideal system would be one in which the sub-stations were so located that approximately the average length of feeder would not exceed 6,000 feet. As I remember, the average length of feeders on two of the largest systems here in Chicago is something like that, say, 6,000 or 7,000 feet, so that the conditions are pretty close to the ideal.

*Mr. H. M. Wheeler, M. W. S. E.:* In re-designing the feeder system of the Chicago Railways Company, the writer has developed the following graphical methods, and has found his results to check very closely with the more elaborate theoretical method just described.

The general problem may be stated thus: (1) To divide the trolley system into sections; (2) To determine the load on each section; (3) To obtain the proper size of positive feeder for each section. These points will be taken up in order.

1. To divide the trolley system into sections. (a) On map of trolley system, place dots at locations of the various power stations, join these by straight lines and draw perpendicular bisectors to same. These bisectors will form irregular polygons about each of the power stations, thus determining the territory most economically fed by it. (b) The actual length of street to use for a section depends upon the district, distance from power station, estimated load, etc. For most purposes use:

TABLE 1. APPROXIMATE LENGTHS OF SECTIONS.

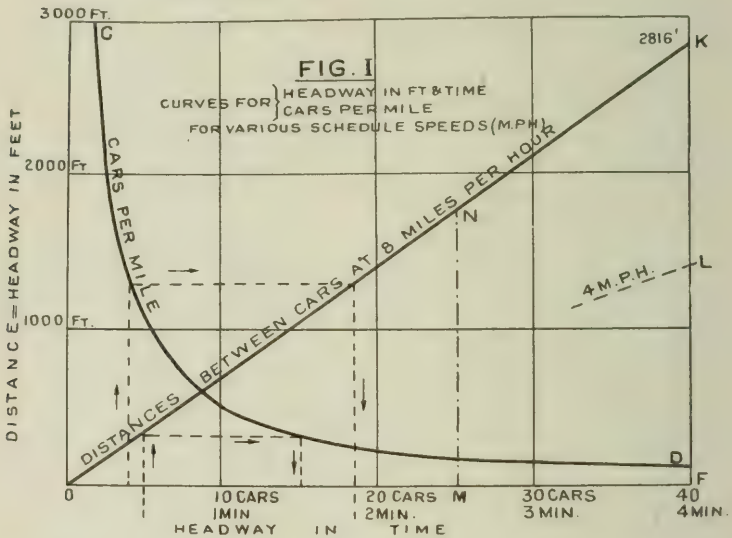
Downtown District,  $\frac{1}{4}$  mile of street equals  $\frac{1}{2}$  mile single trolley  
 Adjacent District,  $\frac{1}{2}$  mile of street equals 1 mile single trolley.  
 Crosstown Lines, 1 mile of street equals 2 miles single trolley.

Of course, if further calculations show the load on any section too light or too heavy, the section can be lengthened or split accordingly.

2. To determine the load on any section. It will be convenient to obtain this load in cars. This load equals length of section (single trolley) multiplied by the cars per mile (for assumed schedule speed and headway). Schedule speed will be expressed in miles per hour (M. P. H.) headway in minutes; distance between cars in feet. The cars per mile are obtained from curves in Fig. 1, which will now be described. (a) Fig. 1. On cross section paper, lay off scales with feet as ordinates, and number of cars as abscissae. Assume cars spaced uniformly, whence we plot curve C D using:

TABLE 2. DISTANCES BETWEEN CARS

At 2 cars per mile, distance between cars equals  $5,280 \div 2 = 2,640$  feet.



At 4 cars per mile, distance between cars equals  $5,280 \div 4 = 1,320$  feet.

At 10 cars per mile, distance between cars equals  $5,280 \div 10 = 528$  feet.

Note: Find other distances in the same manner.

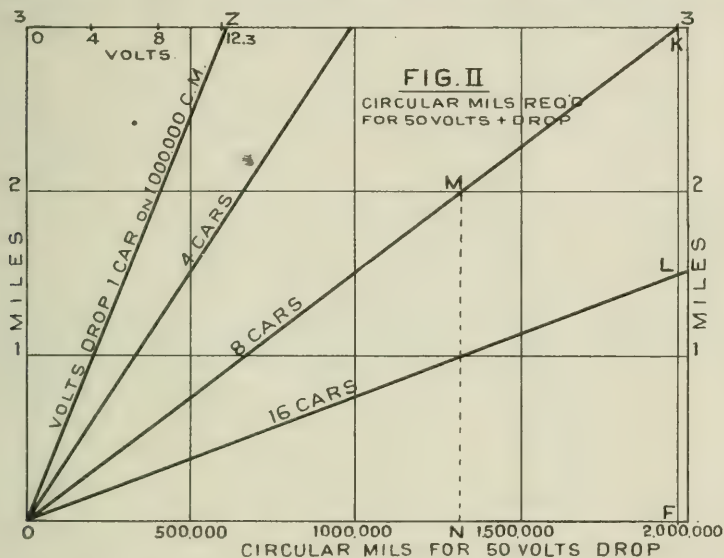
This curve C D is seen to be a rectangular hyperbola of which the equation is  $C D = 5,280$ , when  $C =$  cars per mile, and  $D =$  distance between cars.

(b) We have now to obtain the relationship between cars per mile and schedule speed and headway. (Fig. 1.) Lay off second horizontal scale for headway in minutes. At 8 M. P. H. and 4 minutes headway, the distance between cars is feet per

minute times 4, or  $\frac{8 \times 5280}{60} \times 4 = 2816$  ft. This establishes

point K, on F K the 4 minutes ordinate. Draw O K. Then O K is the 8 M. P. H. Locus, *i. e.*, the ordinates below O K are the distances corresponding to the headways. To prove this, take any headway O M and draw ordinate M N, cutting O K at N, and let X be corresponding distance. For same schedule speed, distance between cars will vary as the headways, whence  $X : F K = O M : O F$ , but from similar triangles  $M N : F K = O M : O F \therefore X = M N$ .

The line O K is plotted to distance and headway; the curve C D is plotted to distance and cars—distance being to same scale



on each. We pass from one to the other at equal distances, *i. e.*, by horizontal lines. Example: Assume  $\frac{1}{2}$  minute headway, project up to line O K, thence horizontally to curve C D, thence down to cars, and obtain 15 cars per mile at 8 M. P. H. By assuming 4 cars per mile and reversing the process, we obtain a headway of 1 minute 52 seconds.

(c) Since for constant headway, distances will vary as the schedule speeds, the 4 M. P. H. Locus will cut F K at L =  $\frac{1}{2}$  F K; the 16 M. P. H. Locus at P = 2 F K, etc.

(d) Where two car lines run over the same track, the combined headway =  $\frac{H \cdot h}{H + h}$ , where  $H$  = headway of first,  $h$  = headway of second.

## (e) TABLE 3. SCHEDULES AND HEADWAYS.

Downtown District—4 M. P. H.—1 minute headway.

Adjacent District—8 M. P. H.—1 minute headway.

Crosstown Lines—8-12 M. P. H.—4-6-8 minutes headway.

(f) Multiply cars per mile  $S$  (2) by length of section  $S$  (1) and obtain load in cars to use in  $S$ -(3).

3. To obtain the proper size of positive feeder for each section. (a) When cars are uniformly distributed over a section, the drop at the end of the section is the same as the drop when all the cars are bunched at the middle of the section. For purposes of drop, find length of feeder by taking routed distance from power station to the middle point of the section. Assume 75 amperes per P. A. Y. E. D. T. car, 50 volts maximum positive drop and carrying capacity of cable as per table below (adapted from Board of Supervising Engineers).

TABLE 4. CARRYING CAPACITY OF L. C. CABLES.

Circular Mils.	Insulation.	Amperes	Number of cars load.
1,000,000	5/32" Paper	1,000	13
1,000,000	5/32" Rubber	800	11
500,000	5/32" Paper	600	8
500,000	5/32" Rubber	500	7

(b) Fig. 2, plot miles vertically, circular mils horizontally. One mil-mile of copper has resistance of 54,674 ohms. To obtain feeder for 8 cars, 3 miles distant, 50 volts drop, apply ohms law  
length x resistance per mil-mile

$E=I R$ , remembering that  $R=\frac{\text{length} \times \text{resistance per mil-mile}}{\text{circular mils}}$

Whence  $50 = 8 \times 75 \times 3 \times 54,674 \div \text{circular mils}$ ; solving, circular mils = 1,968,264. Plot point K at 3 miles, 1,968,264 circular mils; draw O K. This line O K gives relationship between length (of feeder) and circular mils for 8 cars. Example: at 2 miles find point M on O K, project down to N on base line and obtain 1,300,000 C. M. as size of necessary positive feeder. As this is an odd size, and as 1,000,000 C. M. cable has ample capacity (Table 4), we can use 1,000,000 C. M. cable, but the drop will then be inversely as the circular mils, *i. e.*,  $13/10$  of 50 volts = 65 volts. If 1,500,000 C. M. cable is used the drop will be  $10/15$  of 50 = 33 volts. As an additional check, use line O Z, which shows relationship between miles (length of feeder) and volts drop for one car on 1,000,000 C. M. feeder. In example above for 2 miles, drop per car = 8.2 volts, whence for 8 cars = 65.6 volts.

(c) Since for constant size of feeder and constant drop the load will vary inversely as the length, the 16 cars line will cut F K at L =  $\frac{1}{2}$  F K; the 4 cars line at P =  $2$  F K, etc.

(d) In general, feeders should go by the most direct route and should never feed back. The 1,000,000 C. M. cable is the most convenient size and will scarcely ever carry sufficient overload to endanger machines at the station.

(e) When sections are bussed between two stations, either feeder should be able to carry the section alone. When both such feeders are working, the net drop will equal the product of the separate drops, divided by their sum, or  $X = \frac{V v}{V + v}$ .

# IMPROVEMENTS SUGGESTED IN UNDERGROUND CONDUIT CONSTRUCTION FOR LARGE TRANSMISSION SYSTEMS.

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Edw. N. Lake, M. W. S. E.

*Presented February 23, 1910.*

## I. GENERAL.

### 1. Introduction.

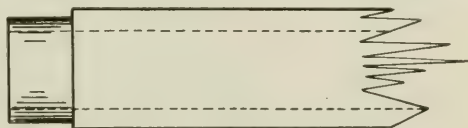
The use of ducts for installing electric conductors underground is a practice of comparatively recent years. The ducts were primarily a means for placing cables underground and a convenience for repairing and replacing them. In more recent times, however, with the large increase in the amounts of energy transmitted, the additional feature—isolation of the cables—is exceedingly important.

In a very few years' time we have seen the rise and fall, so far as large systems are concerned, of a large number of different forms of ducts. The various forms of wood and the pump log type, the Dorset asphaltic concrete forms, the 10 by 10 in. terra cotta, shown in Fig. 1, are now all practically obsolete and the iron pipe and cement lined pipe are only rarely to be found at this time. The forms at present used are the cement or stone duct, fiber pipe, and the multiple and single form of vitrified clay duct. All of these forms of duct are installed in the same general manner in concrete, and the methods are practically the same as have been used for fifteen or more years.

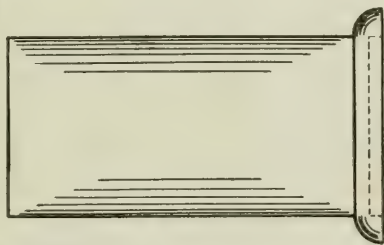
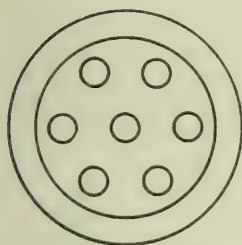
A change or an improvement in underground conduit construction, because of the effect of precedent and inertia is sure to encounter strenuous objections all along the line. The men in the trench who handle the material and lay the duct; the gang bosses and foremen who are responsible for progress and labor costs; the men who install the cables; the man who is held responsible for the safety of the cables when in place; and the man who is responsible for the investment made, will all have their say—will all "take a shot at the new stunt," as they say, and the new plan must show some very decided advantages or it will not be able to run the gauntlet of criticism and reach the point where someone in authority will say that it is worth trying out.

The suggested improvements in this paper are almost all made with reference to the comparatively new ideas of isolation and protection of the cables for which the conduits are built. In this as in all other matters of engineering design, where prevention and insurance are the basis, the precautions taken and the

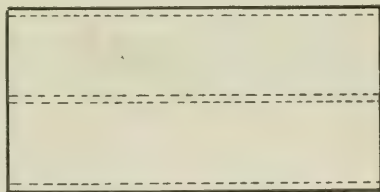
amounts expended for safeguards will depend entirely upon the importance which is attached to these matters by the men who are responsible for the designs and the expenditures. Numerous cases of burnouts which have seriously affected a larger or smaller number of cables adjacent to the defective one can be cited by almost any engineer who has had to deal with underground conduit installations for the distribution of large amounts of electrical energy. So there is apparently a real need of some



PUMP LOG.



7 HOLE DORSETT



10" X 10" TERRA COTTA

Fig. 1.—Some Obsolete Forms of Duct.

improvements which will insure against such spread of trouble from one duct to another.

## 2. *Vitrified Clay.*

The best heat-resisting and arc-resisting material which is available on a commercial basis at this time is undoubtedly vitrified clay.

Where a material is desired for use in contact with flame or intensely heated gases, as in furnace linings, boiler bridge walls,

or flue linings; where a receptacle is wanted in which to enclose a high tension insulator when it is placed in the kilns; where a material is to be subjected to the great volume and intensity of heat that emanates from molten metals; everywhere that heat and flame are to be resisted by direct contact, some form of hard-burned clay is used. So when a material is wanted for underground conduit construction that will resist the intensity and volume of the heat of the electric arc, we very naturally turn to vitrified clay in the form of ducts.

### 3. *Absorption Tests.*

When a small quantity of water is closely confined and exposed to sudden and intense heat, it acts with all the violence of a high power explosive. Tubular steam boilers without water and with the bottom plates overheated have exploded with most terrific force upon turning in only a small quantity of feed water. A drop or two of water in a ladle into which molten metal is poured explodes with disastrous effects. A very small amount of water confined in old scrap castings, such as old pump valves, when not properly broken up and inspected before being thrown into the melting furnace, has been known to explode with force enough to wreck a cupola.

Due to this so-called explosive power of water, it is believed that the walls of a clay duct, which might otherwise withstand the heat of a burnout, if it contains a sufficient amount of moisture, will be rapidly disintegrated in successive layers by the sudden vaporization of the water confined in the interstices, under the action of the intense heat of the arc. Hence, that vitrified clay duct is best for large power distribution systems which will absorb the smallest percentage of moisture.

The following, it is believed, represents in a general way the relation of vitrification and glaze to absorption in this class of duct material:

Vitrification.	Glaze.	Absorption.
Good.	Good.	Minimum.
Good.	Poor.	Slightly larger.
Poor.	Good.	Larger.
Poor.	Poor.	Maximum.

You will see from these relations that if an absorption test is made a part of the duct specifications, the percent for a whole piece of tile will differ from that of a fragment, and the fragments will differ with the amount of glazed surface.

A ready means of testing absorption is to take a sliver from a broken duct, preferably one with one surface glazed, and dip it in ink. By breaking off fragments from the tip end, the following will then be observed:

1. If glaze and vitrification are good, the ink will not penetrate the material.

2. If glaze is good and vitrification is poor, the ink will not penetrate through the glaze, but will penetrate a considerable layer of the unglazed material.

3. If glaze and vitrification are both poor, the penetration will be about the same on all surfaces.

The percentage of absorption permitted will depend upon the importance which the engineer attaches to the matter, and the local conditions as to the kind of duct that can be delivered to the trench at a fair price.

One specification used here in Chicago requires not more than 2% absorption in 24 hours in the whole piece, and 3% in fragments having about 50% of surfaces glazed. Another specification requires not over 5% absorption, without defining the condition as to the whole or broken pieces.

## II CONDUIT CONSTRUCTION

### 4. *Single Duct and Multiple Duct*

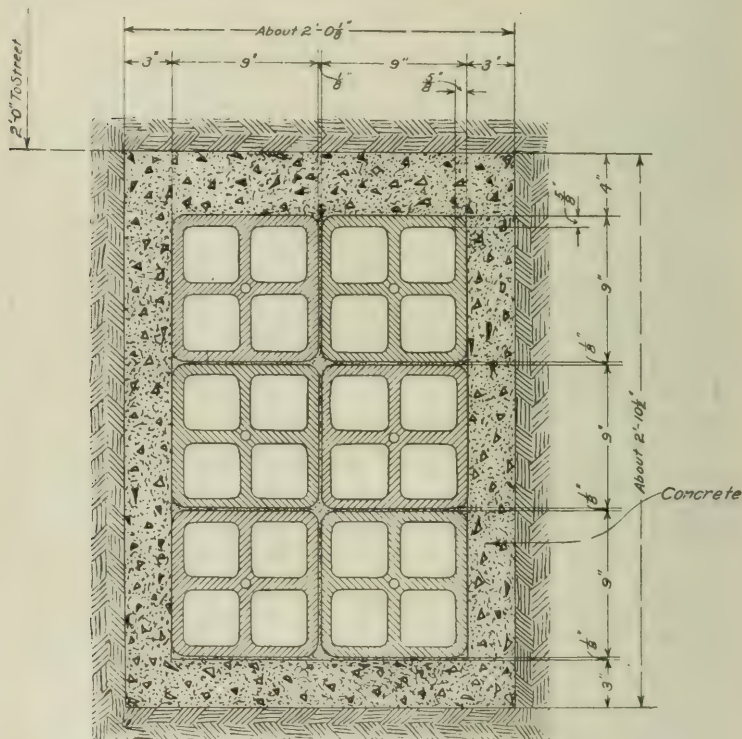
This is an old subject and practices are pretty well crystallized with reference to the use of single and multiple duct; each has its particular field in which it practically monopolizes the construction, but a word here may not be entirely at variance with the scope of this paper.

For telephone cables, and for all cable systems where the number of heavy cables is not large and where no special consideration of the possible spread of trouble from one cable to its neighbors is thought to be necessary, the multiple duct, Fig. 2, on account of economy of space and convenience in handling, is the logical choice of vitrified clay duct. But for systems which carry large groups of cables where tens of thousands of kilowatts may be concentrated upon a burnout, and where cable separation and isolation must be given its due consideration, the single duct construction, Fig. 3, is believed to be better and is most generally used.

It might be said, in passing, that the single duct is a much more flexible construction for congested city locations where a great deal of maneuvering is necessary to get around or over, or under, or through obstructions. These obstructions, which are the uncharted reefs of the underground territories of any city, are both the joy and the grief of underground conduit work. If it were always a clean ditch, such as Fig. 4, and with no obstructions, underground conduit construction would be monotonous and uninteresting. If it were not for the difficult intersections, of which Fig. 5, reproduced from the *Engineering Record*, is a good example, and the satisfaction of getting a good line through them, some of the men who have followed the work for half a lifetime would have dropped out long ago.

### 5. The Corners of the Duct.

The present standard single duct construction, using  $3\frac{1}{4}$  or  $3\frac{1}{2}$  in. square bore duct, which is used in most of the larger systems, is shown by Fig. 3, and is believed to represent the best engineering practice for large power systems at the present time. This construction, when properly installed, provides two walls of about  $\frac{5}{8}$  in. each of vitrified clay between adjacent ducts, and it has been demonstrated in practice that for ordinary burn-outs this is effective in isolating the trouble. In the case of very



SECTION THROUGH CONDUIT

Fig. 2.—Multiple Duct, Standard Construction.

severe burnouts it has been found, however, that there are certain weaknesses in this form of construction. One of these is due to the present form of corners on the duct, which leaves a void of considerable size. Of the space shown between the corners in Fig. 6, only the lower half is usually filled with concrete, so that a severe burnout will communicate laterally through the joints in the ducts and longitudinally through the voids, and thus injure cables in adjacent ducts.

In Fig. 7 is shown an example of this defect, taken from a drawing exhibited by Mr. D. W. Roper, of the Commonwealth Edison Company, of Chicago, in a paper which he presented here something over a year ago. It is apparent that burnouts of this kind involve a large expense to repair the cables and ducts; the danger to connected apparatus is also a factor to be considered, so that improvements which may be made at a reasonable cost which will reduce the liability of such loss are very desirable.

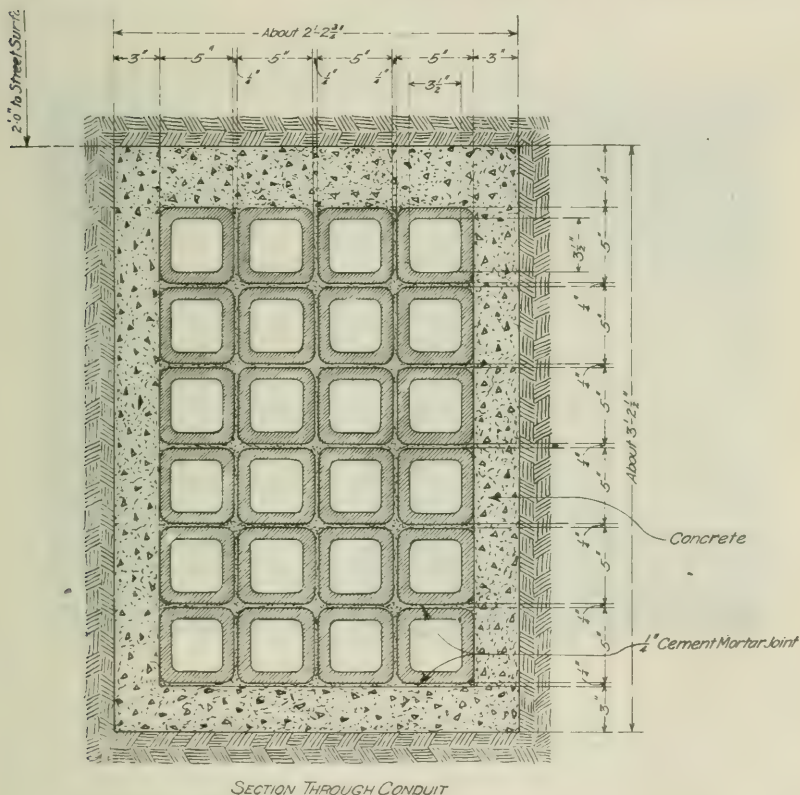


Fig. 3.—Single Duct, Standard Construction.

It is believed that one simple improvement in the duct would consist of slightly modifying its shape so as to reduce the void at the corner to such an extent that it may be completely filled by the mortar in the process of laying. By comparing Figs. 6 and 8 it will be seen that by a slight change in the outside radius of the corner of the duct, the area of the void at the corner of four ducts is very materially reduced. By going over the drawings with a planimeter, it was found that this corner

space was in a ratio of six on the present form to one on the proposed form.

This change in form was submitted to several of the leading duct manufacturers, and while all agreed that it was not impractical to manufacture the duct in the proposed form, there were the usual objections that are urged to any innovation. The following are extracts from the letters received.

**Manufacturer No. 1, First Letter.**

"In direct answer to your inquiry, we may say that it is possible to manufacture your proposed form, but that we



Fig. 4.—A "Clean Ditch."

have given our present form as square a corner as is economical in manufacture. We estimate that it would cost at least 3% more to manufacture your proposed form on account of the additional waste which would be caused in the machine running.

It is necessary to run the clay very stiff to manufacture this particular form of conduit. With stiff clay the nearer you approach a square corner the more apt is the clay to scale up on the dies. The result would be a roughened cross-cracked corner, which would not be acceptable and would have to be culled out."

**Manufacturer No. 1, Second Letter.**

"It would be to your advantage, in the contemplated

change of style of conduit, not to require any change on the inside corner of the duct. In trimming the tile to bevel the inside edges of the duct, the square corner would be apt to be slighted in the trimming.

On advice from our superintendent at the factory I may say that we can make this outside change as per your blue print."

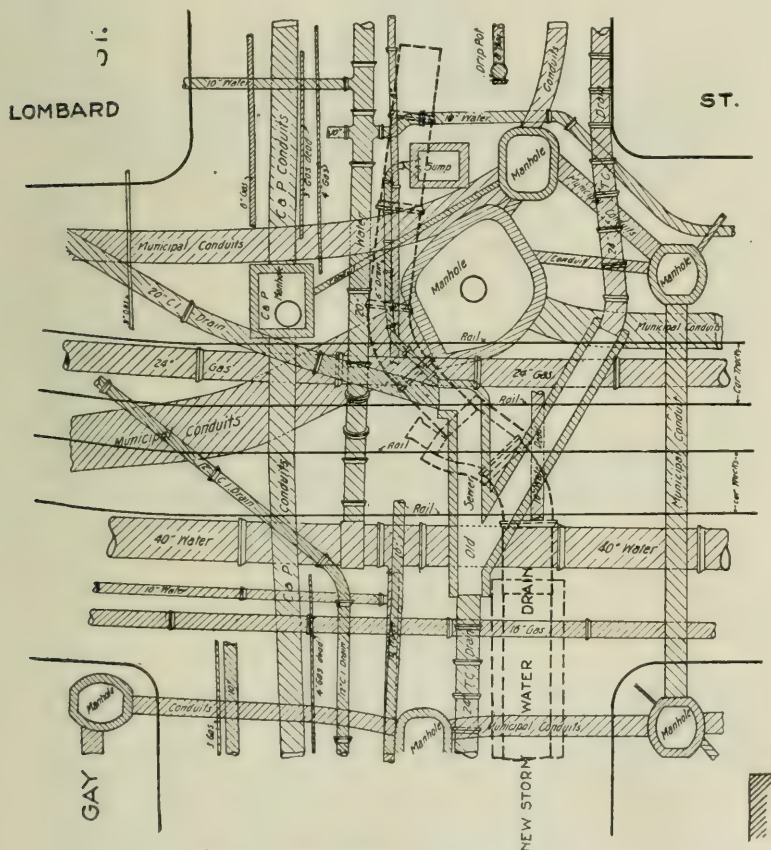


Fig. 5.—"A Difficult Intersection."

#### Manufacturer No. 2, First Letter.

"We see no practical objection to the tile being manufactured in the form called for by your design, excepting, of course, new dies would be required in order to manufacture the tile in the exact shape called for."

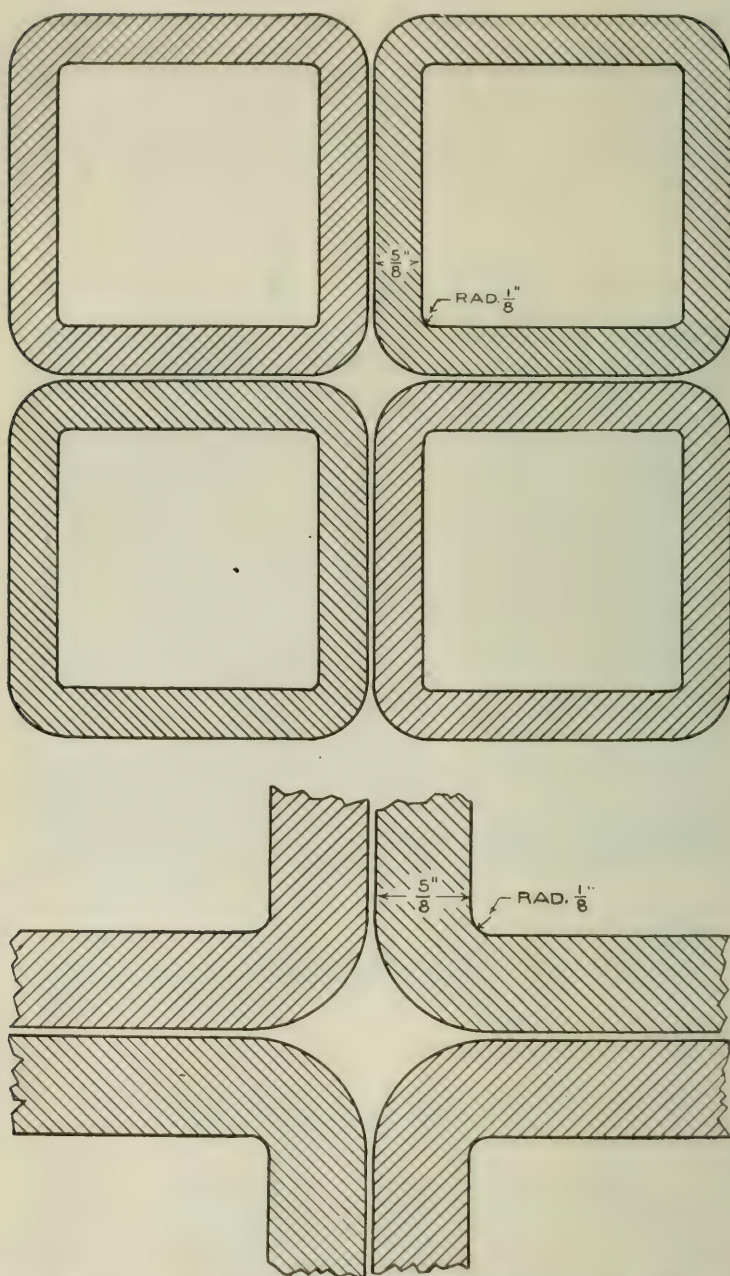


Fig. 6. Present Form of Corners of Clay Ducts Showing Large Voids.

## Manufacturer No. 2, Second Letter.

"Since my former letter I have consulted with our factory superintendent more fully, and he is quite adverse to changing the present form of our  $3\frac{1}{2}$  in. square conduit in accordance with your sketch, for the reason that the unequal thickness of the shell at the corner will materially retard the drying of these conduits, to what extent we cannot say until some of the blocks are manufactured, and whether or not an

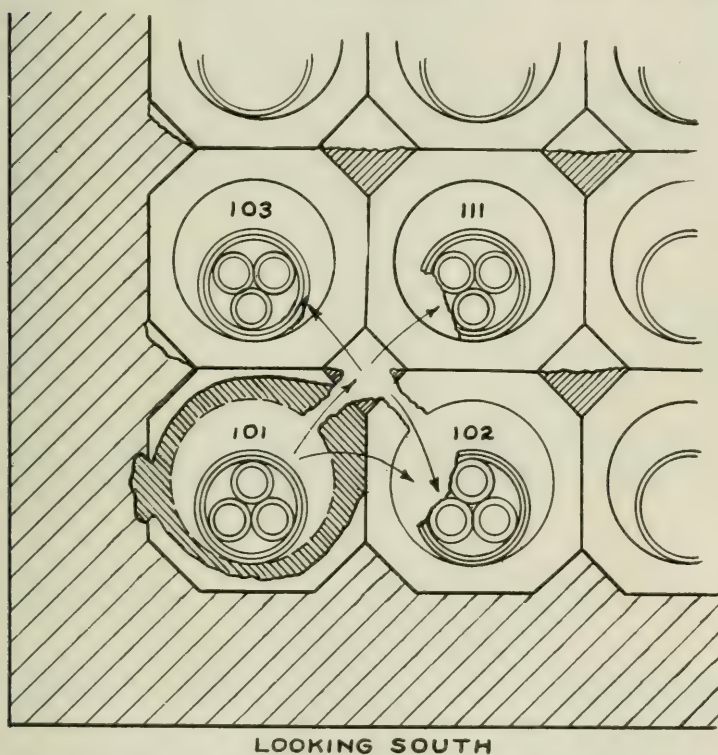


Fig. 7.—Example of Burnout, Spread of Which Was Apparently Due to Large Voids.

increase in cost would result therefrom for this reason is problematical."

## Manufacturer No. 3.

"Upon a recent visit at our factory our superintendents were consulted, and it was the general opinion that the section could be made, but not without an unusually large percentage of loss in the manufacture, because of the inclination

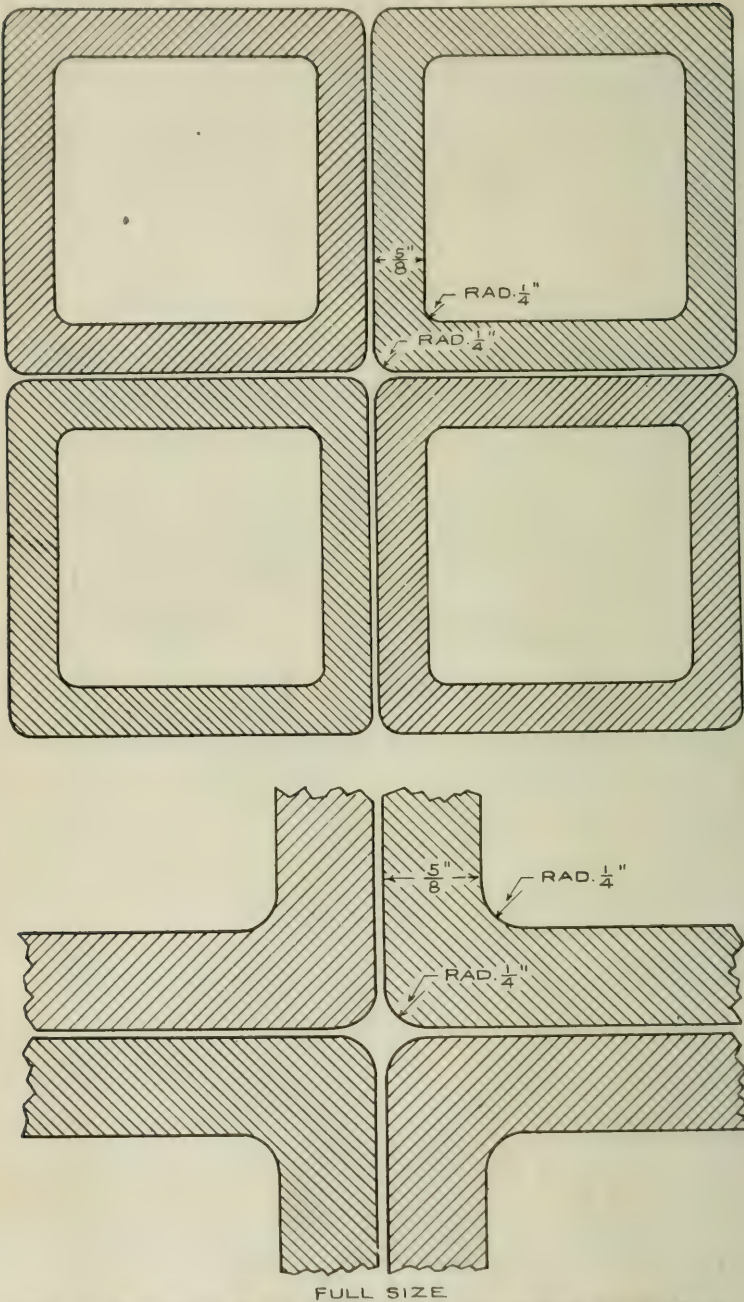


Fig. 8.—Suggested Form of Corners of Ducts With Small Voids.

of clay wares to move during the burning period, and thus make the finished product undesirable, because of its having lost its shape."

#### Manufacturer No. 4.

"This type of conduit can be manufactured as easily as any of the present standard types of single conduits. Its cost of manufacture would be greater, however, due to the much larger amount of clay in its ends than in other types, causing uneven shrinkage and flaring of the ends in the drying out process, and a splitting and cracking of the ends in the burning process.

The conduit would necessarily be heavier than other types of singles and the process of manufacture would be slower. The additional cost in manufacture over the other types would be approximately  $\frac{1}{4}$ c per duct foot, and its manufacture would not be profitable on small amounts as it would materially interfere with our output of standard conduits."

From the foregoing and from conversations with the manufacturers' representatives, it is apparent that some considerable inertia must be overcome, but it is quite certain that if competitive bids were requested on a large quantity of duct with the proposed form of corner, it would be found that the manufacturers would be willing to make the duct without any additional cost over present forms, and it is very probable that the product would be just as good as the material in the present form of duct.

#### 6. *Definite System of Breaking Joints*

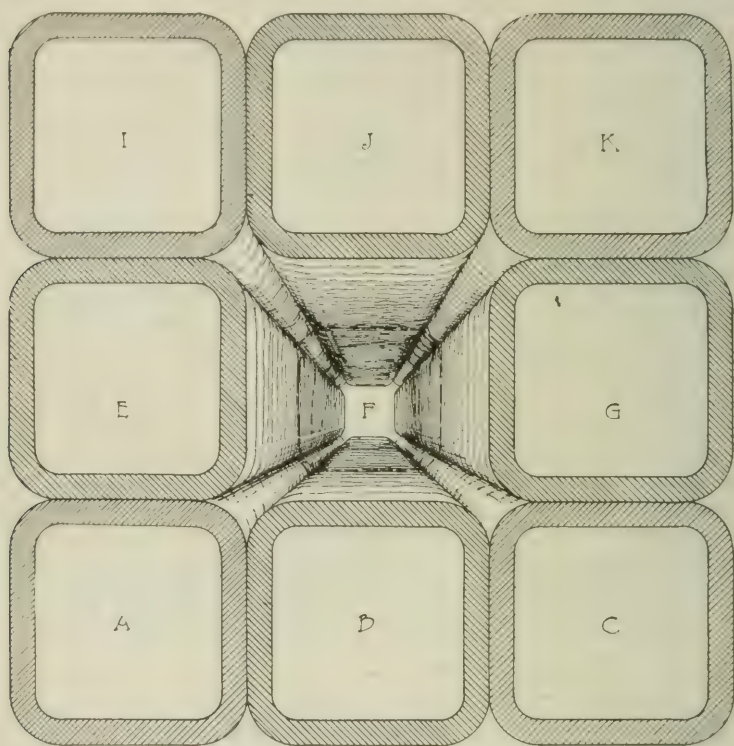
Another difficulty encountered in the present construction is that, unless very careful supervision is exercised, the joints in the ducts will not be properly staggered as they are laid.

Take, for example, the middle duct in a 9-duct section, as duct *F* in Fig. 9 which has eight ducts adjacent, whose joints must be staggered with reference to its own joints. This is usually done so far as the four ducts adjacent to the four sides are concerned, as ducts *E*, *J*, *G*, and *B*, but it often occurs that the ducts adjacent to the corners, such as *I*, *K*, *C* and *A*, have not their joints properly staggered.

The result of this is that burnouts may occur in a duct, say duct *F*, which would not affect cables in the ducts *E*, *J*, *G*, or *B*, but would melt the lead and destroy the insulation of cables in ducts *I*, *K*, *C*, and *A*.

A rigid adherence to a definite plan of breaking joints is not usually followed, but would be of decided advantage in the present construction. For a conduit section of tiers of four ducts in width, the plan shown on Fig. 10 is effective. This is so arranged that joints in adjacent ducts will not be nearer than one-fourth of a standard length, or  $4\frac{1}{2}$  in. apart. While this would undoubtedly

ly reduce to some extent the liability of the spread of a burnout, the spacing of  $4\frac{1}{2}$  in. minimum between joints in adjacent ducts is manifestly too small, even if it could be rigidly maintained,



SECTION THROUGH DUCT  
CENTER DUCT REMOVED

Fig. 9.—A Group of Ducts, With Center One Removed to Show Necessity of Breaking Joints.

which is extremely difficult under practical construction conditions.

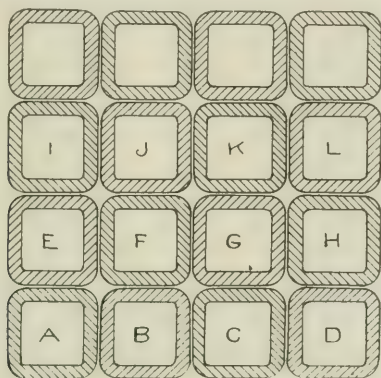
### 7. Single Duct in Multiples

One improvement which has been considered consists of installing the present single duct in multiples, with an extra separation by concrete between the multiples. In Fig. 11 is shown a section of this construction, and Fig. 12 shows the corresponding plan of breaking joints. This construction does not overcome entirely the objection due to voids at the corners, and since joints will be as close as  $4\frac{1}{2}$  in., a cable failure may involve adjacent ducts in the same group, but it has the advantage of dividing up a conduit line into unit groups which are so thoroughly

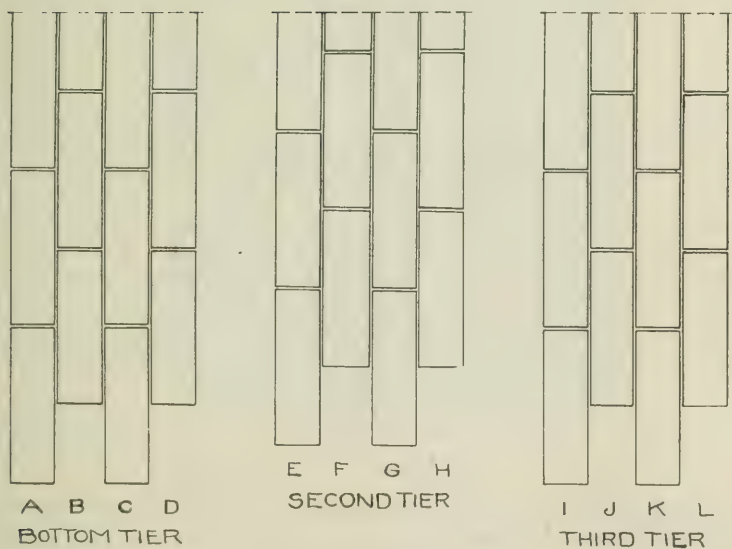
isolated that the possibility of a cable failure in one group injuring the cables in an adjacent group is very remote.

### 8. Single Duct in Tiers

Another plan, shown in Fig. 13, is a modification of the



16 DUCT SECTION.



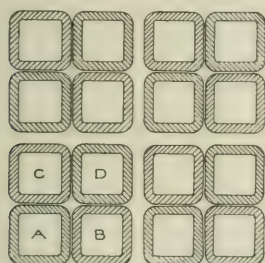
PLAN OF TIERS

Fig. 10.—Plan of Breaking Joints, Single Duct, Standard Construction.

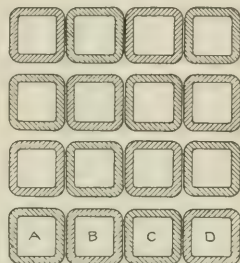


by two  $\frac{5}{8}$  in. thicknesses of vitrified clay and 1 in. or more of concrete.

Practical conduit men will look askance at figures upon cost since there is such an exceedingly wide variation in costs, due to soil, obstructions encountered, weather conditions, and the organization of the conduit gangs. Comparative figures, however, based as nearly as possible upon similar conditions, are here



16 DUCT SECTION



16 DUCT SECTION

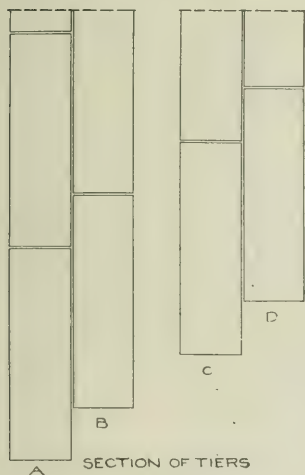


Fig. 12.

Plan of Breaking Joints for Single Ducts in Multiple.



PLAN OF BOTTOM TIER

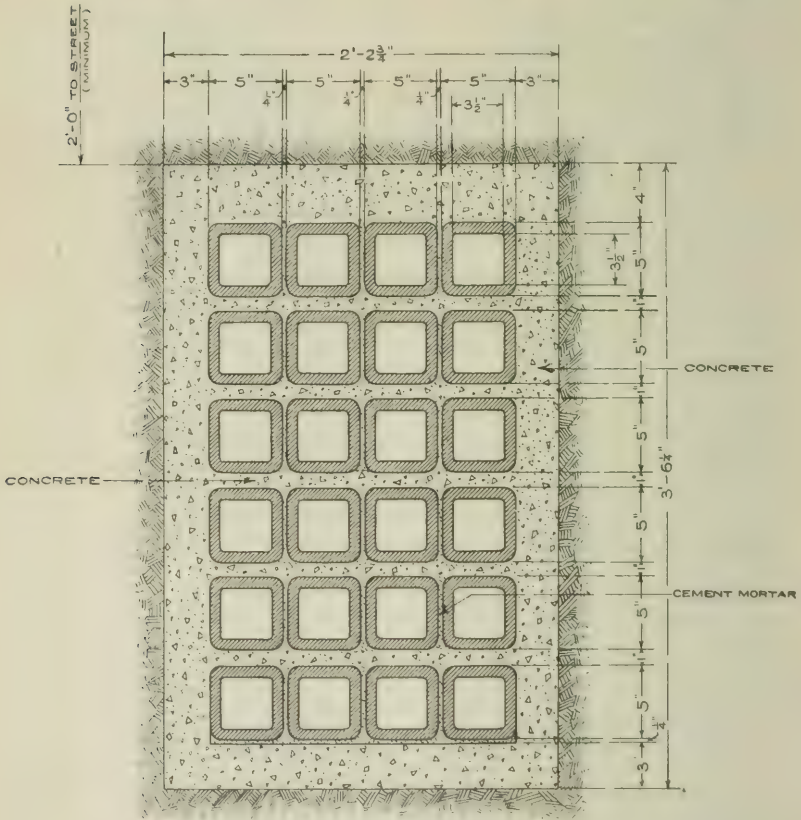
Fig. 14.

Plan of Breaking Joints for Single Ducts in Tiers.

presented to show the relative costs in cents per duct foot of the three different methods of conduit construction.

Conduit Section	Standard Single Duct (Fig. 3)	Single Duct In Multiple (Fig. 11)	Single Duct In Tiers (Fig. 13)
4 Duct	27.6	27.6	28.1
6	22.0	22.1	23.0

8	19.3	19.7	20.4
9	18.3	...	19.3
10	18.0	19.6	19.2
12	16.4	17.7	17.5
15	15.0	...	16.3
16	14.9	15.6	16.0
18	14.6	...	15.9
20	14.2	15.1	15.3
24	13.3	14.3	14.5
Average	17.60	18.96	18.68



SECTION THROUGH CONDUIT

Fig. 13.—Single Duct Laid in Tiers.

Taking the standard single duct construction shown in Fig. 3 as the base, a comparison of percentages is given below, and also in the last column is given the cents per duct foot of extra costs which would be involved in using the unit tiers.

Conduit Section	Standard (Fig. 2)	Multiple (Fig. 9)	Tiers (Fig. 11)	Extra Cost of Tiers
4	100%	100%	101.8%	.5
6	100	100.4	104.5	1.0
8	100	102.0	105.7	1.1
9	100	.....	105.4	1.0
10	100	108.8	106.6	1.2
12	100	107.9	106.7	1.1
15	100	.....	108.6	1.3
16	100	104.7	107.4	1.1
18	100	.....	108.9	1.3
20	100	106.3	107.7	1.1
24	100	107.5	109.0	1.2
Average	100%	107.7%	106.1%	1.08c

It will thus be seen that the conduit construction in tiers involves an increase for the average of all of the conduit sections considered, of about 6% or about 1c per duct foot. An increase in conduit cost of 6% would seem at first to be more than is justifiable for such improvements. But when considered as additional insurance against cable losses, it is found that the 1c per duct foot of increased cost is only a nominal insurance rate. The value of cable per foot of duct may be \$1.00 to \$1.50, and the connected apparatus which might be endangered by cable burn-outs may be of an additional value equal to \$1.00 to \$1.25 per foot of cable. Taking the minimum of \$2.00 per foot for the value of cable and connected apparatus as the basis, the additional cost of 1c per duct foot for construction in tiers is equal to an insurance rate of only 50c per \$100.00 for the first year. The cost for subsequent years will be the interest charge on this additional cost, which at 6% would be 3c per \$100.00. Upon this basis the additional cost would appear to be not only entirely justifiable but highly to be recommended.

#### 9. Round Bore Duct For Important Lines

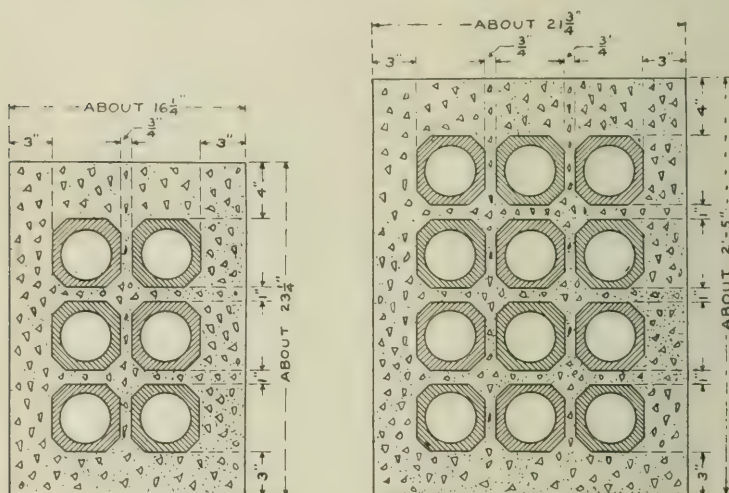
Square bore duct has come into general use because two or more cables can be installed with greater ease than in the round bore, and because it is a favorite with the men at the trench on account of greater ease in handling and laying.

Round bore duct of the same size takes less clay to make, and is lighter in weight; there is also less waste due to swelled ends in the drying process, and a smaller number of culls from the kilns, because the shape is such that when piled for burning the heat is distributed more uniformly, and the material is therefore generally better burned and better vitrified.

In ordinary low tension systems the individual cables seldom carry more than 250 to 500 kw. each. In a high tension system, however, ten to fifteen times this capacity may be transmitted in a single cable. In high tension systems the cables are usually

of such large outside diameter that only one of them can be installed in a duct. For high tension lines and for important low tension lines involving large amounts of power, where a superior construction is desired, a line consisting of round bore single ducts laid in tiers, with an extra space between horizontal ducts, as shown in Fig. 15, would represent, it is believed, the very highest type of construction possible at this date.

A comparative estimate of the cost of this construction and the present standard square duct conduit, assuming identical conditions and taking only the 6 duct and 12 duct sections, gives the following:



SECTIONS THROUGH CONDUIT  
(3 1/2" ROUND BORE DUCT)

Fig. 15.—Round Bore Single Ducts with Horizontal and Vertical Separation.

	Standard Square Bore (Fig. 2)	Round Bore Special (Fig. 15)	Extra Cost Round Bore Special
6 duct per duct ft.	22.0c	23.0c	1.0c
12 duct per duct ft.	16.4	17.6	1.2

This small additional cost would often be more than justified on the important lines of a large system.

#### 10. Duplex Conduit Construction

It is the practice in recent years of those who are responsible for the safety of the cables on an extensive system, to have cables routed by as many routes as are available and practical, so as to minimize the effect of burnouts in interrupting the service on

the system. Where practicable, heavy conduit runs are subdivided and built part on one street and part on another so as to make this routing of cables possible, but this involves a large additional expense since it is apparent that two 12-duct runs on different streets will cost more for excavation, manholes, concrete, and paving than one 24-duct run on one route.

In order to secure in a large measure the advantages of two separate runs with but very little increase in the cost, what is styled the duplex construction will be found to be desirable. This consists simply in dividing the conduit of a run into two sec-

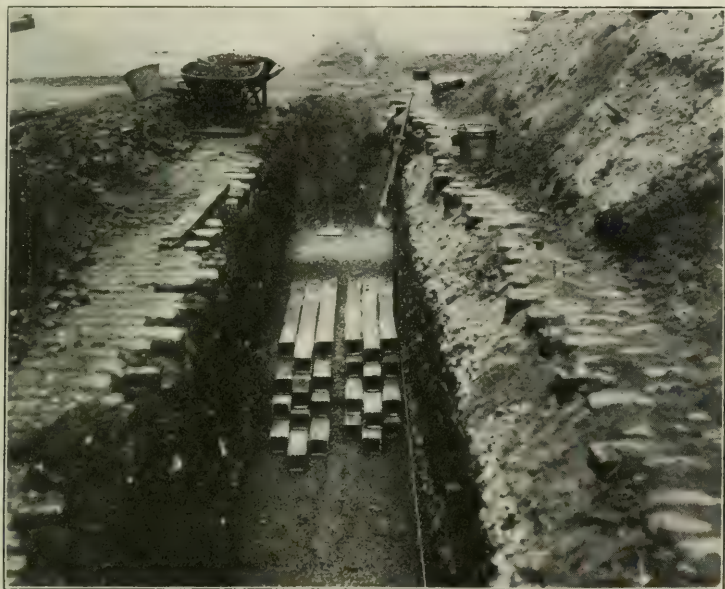


Fig. 16.—Duplex Line of 24 Ducts with a Vertical Concrete Barrier in the Center.

tions, separated by a substantial barrier of concrete. Fig. 16 shows a duplex line of 24 ducts divided into two equal sections, with a concrete barrier of about 3 in. Where the ducts enter the manholes, this spacing is increased to 6 or 8 in. and the cables may be trained on opposite walls of the manhole. The additional expense involved for this construction amounts to only about  $\frac{1}{2}c$  per duct foot on a 24-duct line such as shown.

#### 11. Laterals.

The connections which are made at intervals between the overhead system and the underground system of a street railway are made by means of taps or laterals extending from a manhole through a suitable duct up to the overhead conductor on the pole.

These laterals, although a relatively small part of the system as a whole may, if they are improperly insulated or improperly installed, become the weak points which are the measure of the effective strength of the whole distribution construction.

Present standards of construction have, in the main, proved very satisfactory, but there are some details which, it is believed, can be improved so as to eliminate a certain class of troubles.

It has been observed that the laterals are the points where the conditions appear to be especially favorable for the occurrence of trouble. An apparent cause of failures in the lateral connection is electrolysis, the effects of which are often to be found in the bends of the iron pipe through which the lateral connections are made. This is probably due to the fact that in a conduit system using vitrified clay ducts, the sheath is usually much better insulated from the earth throughout its length than at the point where the lead sheath of the lateral tap comes in contact with the iron pipe constituting the lateral duct. This pipe, if attached to an iron pole or buried in the earth at its lower end, is usually pretty well grounded, and it has been observed that very often there is a good deal of moisture at the bend. These conditions are especially favorable to electrolytic action which, by destroying the lead sheath, brings about, sooner or later, a failure of the insulation with its resulting burnout.

It may also be true that near the border between overhead and underground districts, the insulation at the laterals is subject to unusual strains on account of surges in the overhead system, encountering the capacity effect of the underground lead sheathed cables at these points. In any event, in order to minimize the trouble at these points it is believed that the insulating value of the lateral duct should be about the same as or better than that of the duct in the main conduit line.

The iron pipe lateral construction, shown in Fig. 17, does not provide any insulation, but, as above noted; does prove a danger point on the system. Consideration has been given to other possible forms which would provide some insulation for the lead sheath of the lateral cables. An essential of all lateral construction which is to be kept constantly in mind, is the thorough protection of the conductor against mechanical injury. For the vertical portion on the pole there appears to be nothing better at the present time than iron pipe, so that all of the styles considered agree in having a vertical section of iron pipe. The other illustrations are self-explanatory, showing the 3 in. sewer pipe in Fig. 18 and 3½ in. standard duct in Fig. 19, each having a cast iron adapter to connect the sewer pipe or duct to the iron pipe of the vertical run.

Fiber duct was considered for the vertical run, but it was believed that, when used without protection from mechanical injury, the liability of injuring the conductor would be too great. So a combination of fiber to provide the insulation and iron pipe to afford

the mechanical protection was designed, which is shown in Fig. 20. With this construction the insulation can be carried up the vertical run, which is not possible with the other types.

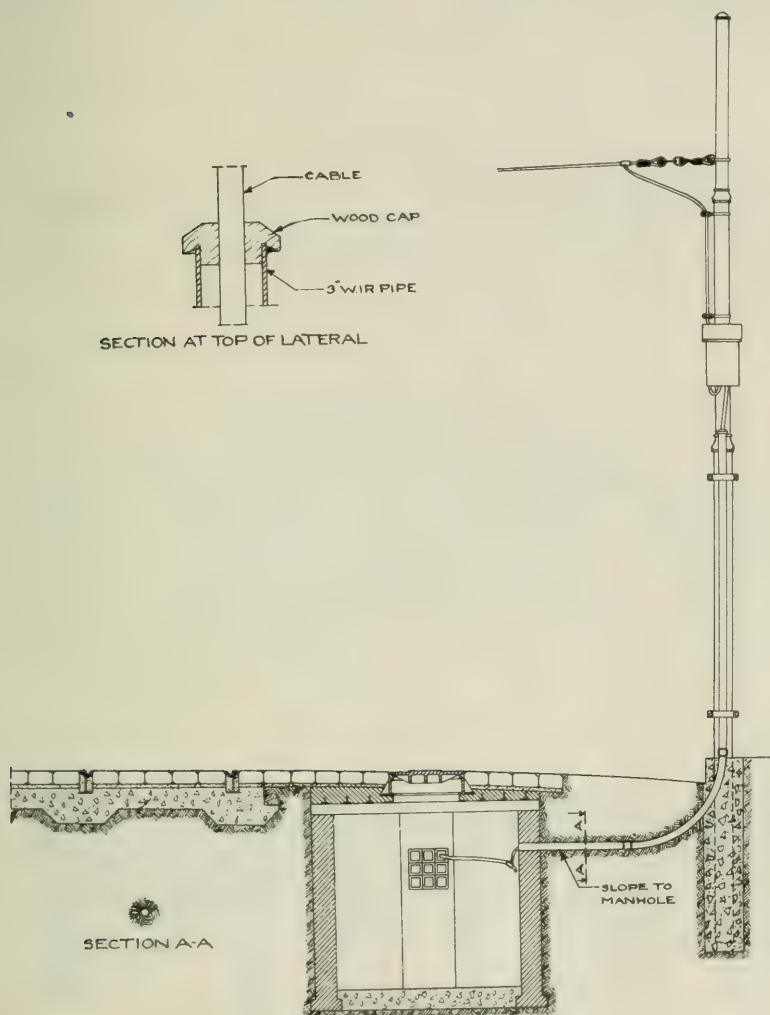


Fig. 17.—Manhole with Lateral Connection in Iron Pipe to the Iron Post.

Some comparative cost estimates are given below, which as will be noted, show that the costs do not vary widely. The totals are as follows:

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	<i>Iron Pipe Only. (Fig. 17)</i>	<i>Sewer Pipe. (Fig. 18)</i>	<i>Tile Duct. (Fig. 19)</i>	<i>Iron Pipe and Fiber. (Fig. 20)</i>
Total cost, each.....	\$ 13.49	\$11.95	\$11.25	\$11.36
Percentages .....	100.	88.6	83.3	84.2

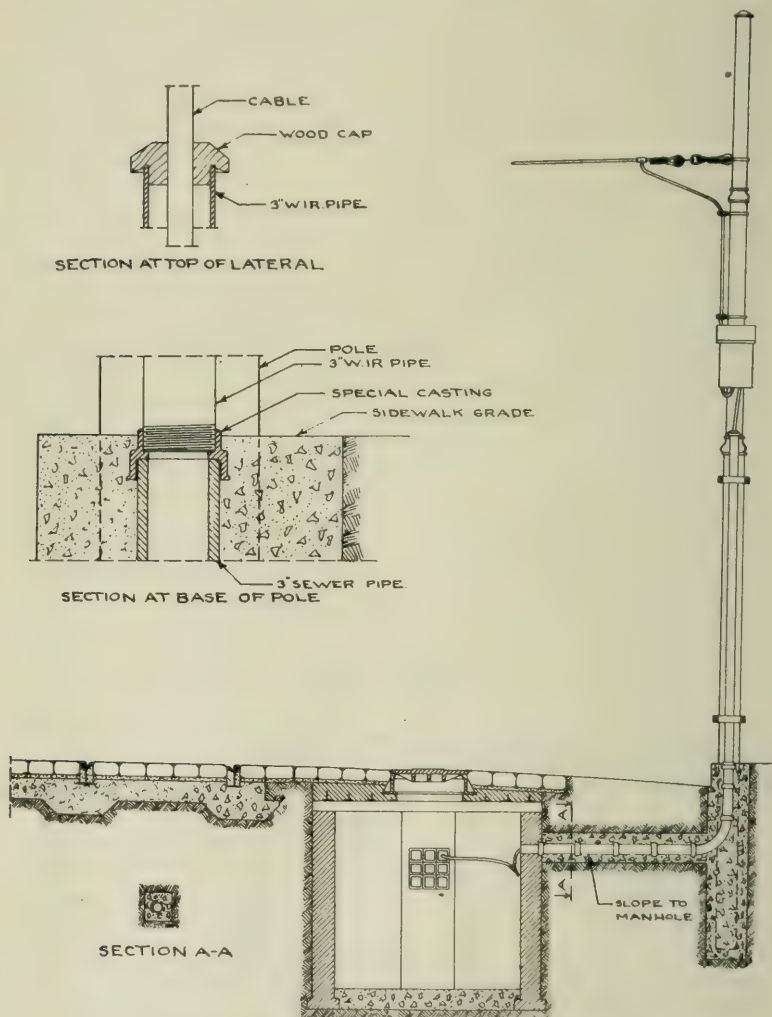


Fig. 18.—Manhole with 3-in. Sewer Pipe for Lateral to Iron Post.

Of these styles it will be observed that the cost of the insulated types are from 11.4 to 16.7% less than the uninsulated, and that the fiber costs only about 5% more than the other two insulated types

and is 11.4% less than the iron pipe. If the fiber was stopped off at the beginning of the vertical iron pipe, as is done with the sewer pipe and tile duct, its cost would be about the same as these forms. It is believed that the fact that the insulation can be carried up

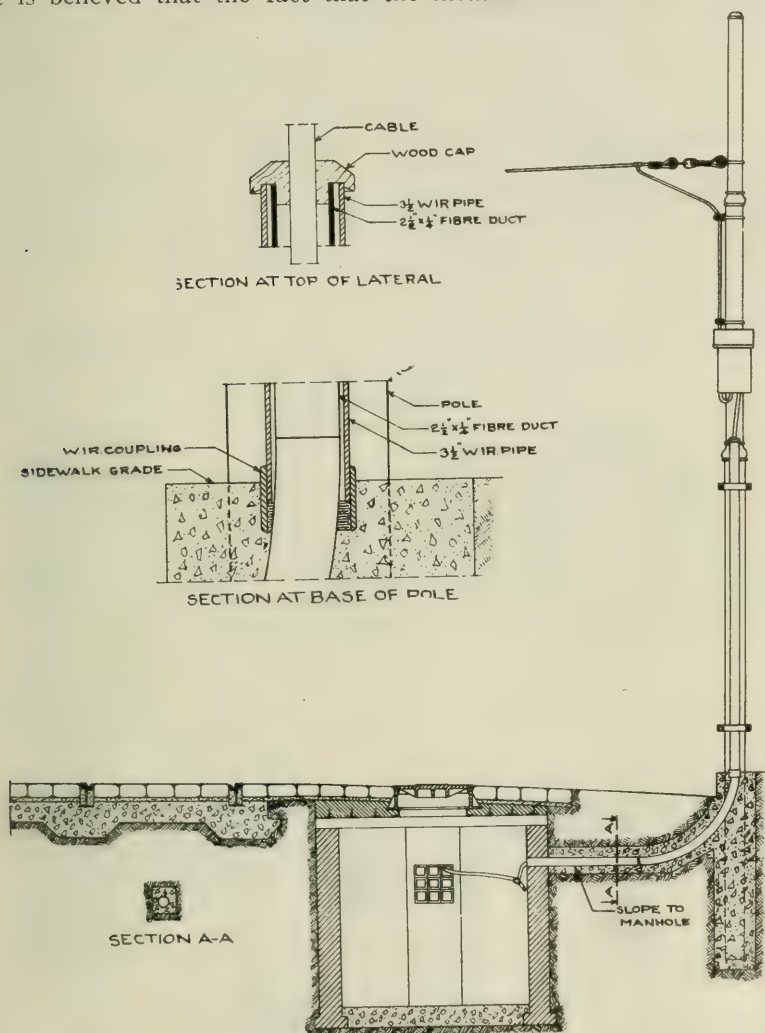


Fig. 19.—Manhole with Standard 3 1/2-in. Duct for Lateral.

the vertical run is very much in favor of the use of the fiber in combination with the iron pipe.

### III. MANHOLE FITTINGS.

So far as the ideas of cable protection and isolation are concerned, the modifications thus far discussed apply more particularly

to the ducts outside of the manholes. In the manholes two additional considerations are involved, viz: the joints in the cables and the matter of accessibility. The importance of the latter will de-

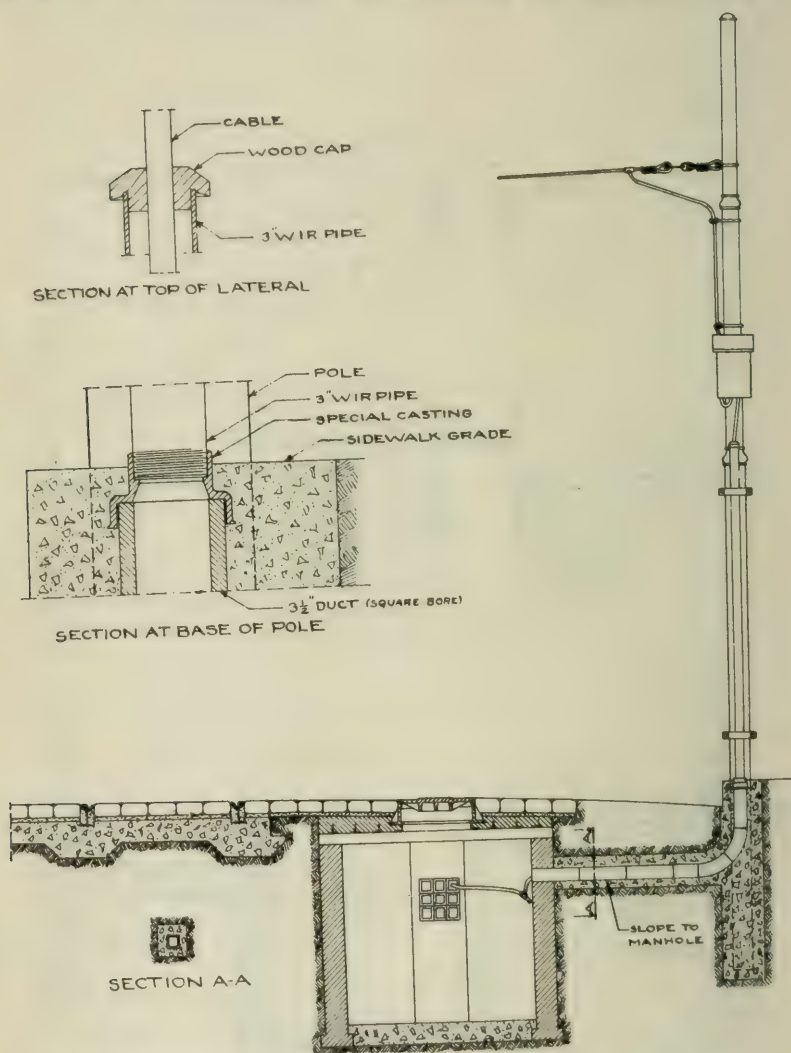


Fig. 20.—Fiber Duct Lateral with Iron Pipe Protection on Pole.

pend upon the perfection of the cable joints and the frequency of cable troubles from other causes.

If cables are thoroughly isolated and protected so that when a burnout occurs only the defective cable is involved, then it is only

a matter of securing access to one cable. The more perfect the protection and isolation of the cables the fewer will be the cables involved in a burnout, and hence the less will be the importance of accessibility. The degree of importance attached to preventative measures by the men in charge, will determine the weight to be given to the questions of accessibility and convenience as against isolation and protection.

Various wrappings of tapes composed of a mixture of asbestos and cotton, of steel and brass strips, and coverings of plastic materials have been used. Each may be particularly adapted to some set of conditions where their use would be perfectly satisfactory, but for the conditions here considered it is believed that in the manholes the same fireproof and arc-resisting materials should be used that are used in the ducts between manholes.

### 12. Fireproof Shelves.

Sheet steel has been used for shelves in manholes, but it has been found that if the metal is thick enough to give a reasonable degree of rigidity, the cutting and fitting is difficult and expensive.

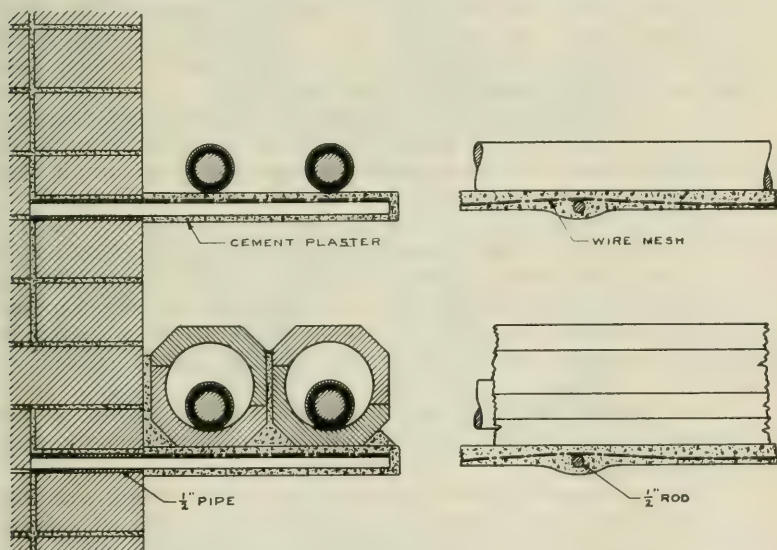


Fig. 21.—Concrete Shelves in Manholes Also Serving as Barriers. Lower Shelf Equipped with Split Duct.

In case of a severe burnout the steel, because of its good conducting qualities and relatively low melting point, tends to spread and augment the trouble rather than localize it.

The upper part of Fig. 21 shows a shelf construction that it is believed is less expensive, more flexible, and with the metal parts entirely covered with cement, so that it is a combined shelf and bar-

rier. The wire mesh may be had in rolls and can be easily cut and fitted with a pair of ordinary snips, and any man who is at all familiar with the use of the trowel can, with a little plasterer's hair mixed into the cement mortar, readily lay these shelves in place. Cables are thus effectually separated into groups by a substantial horizontal barrier of fireproof material. Where only a small number of relatively unimportant cables are involved this construction gives a degree of isolation that is quite sufficient.

### *13. Split Duct.*

For a larger group of more important cables, the split duct construction shown in the lower part of Fig. 22, in addition to the reinforced cement shelves, can be used advantageously. Split duct is made by scoring the walls of the duct as it is excluded from the presses, so that after being burned it can be shipped to the work in whole pieces and there broken into parts for use.

The four different forms of split duct, which are available for this style of construction, are shown: Fig. 22 is the original form, with joints opposite and in a straight line between the two cables. The cement joint, however carefully made, is certain to be more or less imperfect. So with this form the weakest points in the separating wall are placed immediately adjacent and on a line which is the shortest path between the two bores.

Figs. 23 and 24 are forms designed to overcome this objection, but the sharp corners and angles introduced are believed to be objectionable because of the increased breakage that would result when an attempt is made to separate the two half-sections for use.

Fig. 25, which, in point of time, was the first attempt to overcome the objections to the opposite joints of Fig. 22, has the straight scoring which facilitates separation, and its joints, when ducts are laid adjacent, are off-set about  $1\frac{1}{2}$  in. In the first lots manufactured some little difficulty was found in breaking the sections apart, but with closer attention to the dimensions of the scores this was corrected.

Short lengths and  $45^\circ$  and  $90^\circ$  bends can be secured so that almost any series of safe bends for a large cable can be covered with the split duct.

In an average manhole the cost of this construction over that of ordinary metal racks with, say, a double wrapping of asbestos tape, will amount to about \$1.00 per cable per manhole, which, considered as an insurance premium, would be small if the average distance between manholes is 350 feet, and the value of cable and connected apparatus is \$2.00 per foot.

## IV. RECOMMENDATIONS.

For any new underground conduit construction in any large distribution system, the following recommendations are made for the consideration of the engineer in charge of designs, and for the

man who will be in charge of the cables when they are placed in service:

1. Make absorption tests upon the ducts and include an absorption requirement in the duct specification.
2. Use square bore single duct for the standard construction.

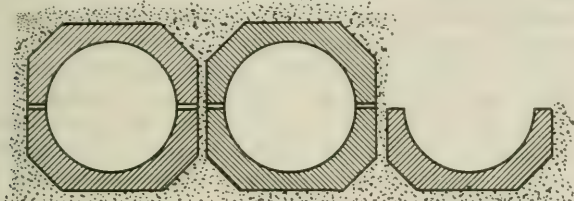


FIG. 22

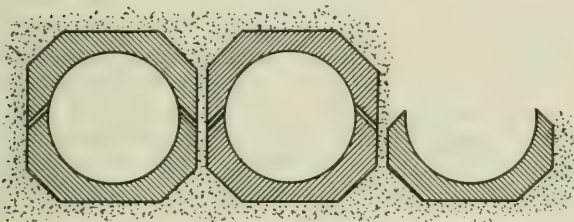


FIG. 23

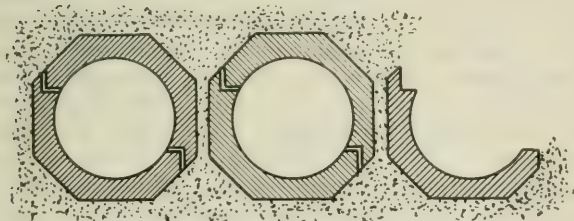


FIG. 24

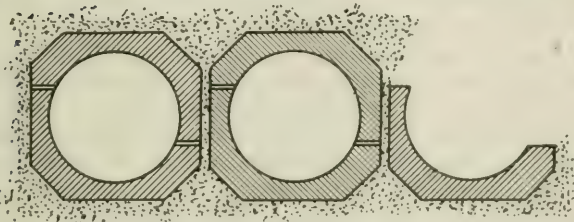


FIG. 25

Figs. 22-25.—Types of Vitrified Clay Split Ducts.

3. Enforce a rigid adherence to a definite plan of staggering the joints.

4. Have all voids between ducts, especially at corners, thoroughly filled with mortar and concrete.

5. Order all future duct with outside corners made on not greater than a quarter inch radius.

6. Install present form of duct in longitudinal tiers, separated by a substantial layer of concrete for important lines.

7. For extra important lines or high tension lines, install round bore duct with horizontal and vertical concrete separation.

8. Construct all lines of 16 ducts or more in the duplex form.

9. For laterals, use fiber protected with iron pipe on the vertical run up the pole, and protected with concrete at the bend and on the horizontal run.

10. In manholes, use reinforced cement shelf barriers for small groups of cables of minor importance. For larger groups of important cable use the split duct in addition to the shelves.

In this audience are men who have been connected with perhaps 80 or 90% of the conduit construction in this city, and naturally it was with some hesitation that I appeared before you this evening with a paper under the title given. I hope, however, that you will consider the paper in the light of suggestions made to bring out discussion, and I trust you will not hesitate to criticise any of the suggestions, especially the poor ones.

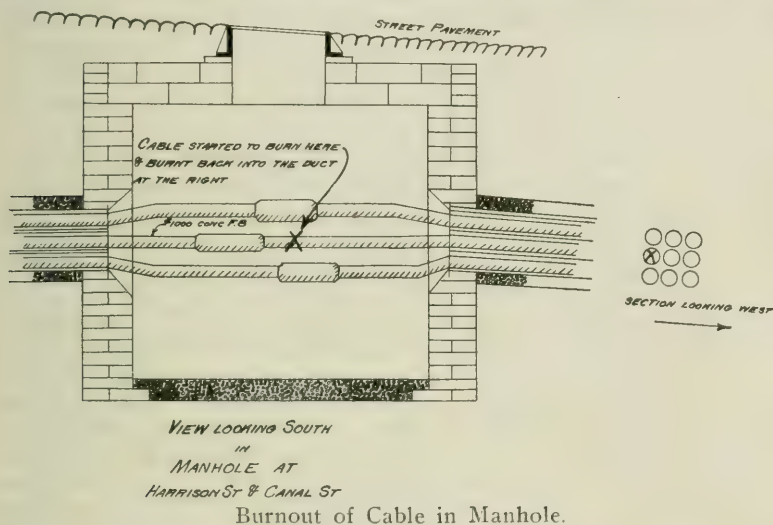
#### DISCUSSION.

*Mr. D. W. Roper, M. W. S. E.:* This paper on underground conduit construction is an interesting one and I agree heartily with Mr. Lake on a number of his statements, which contain some excellent new suggestions. There are, however, a number of his theories with which I disagree. The first of these is the statement that vitrified clay is the best non-conductor of heat and arc-resisting material that we have. Recently I endeavored to find some scientific data for comparing concrete with tile in specific heat, in heat conductivity, and in resistance to high temperatures.

The data which I found was not given in a form admitting of ready comparison, but the experiments forming the basis of the several articles indicated that concrete construction was a poorer heat-conducting material than vitrified tile.

The Commonwealth-Edison Co. had an experience in a burnout some time ago that illustrates this point very well. In Fig. 26 is shown three cables, on one side of the manhole, which occupied the three ducts in one vertical row on that side of the conduit. In the manhole, however, the cable was covered with split tile as mentioned by Mr. Lake. The duct material used in this conduit was of the variety known as stone pipe, which is all concrete except a small band of metal, like a napkin ring, which holds the two abutting ducts in alignment. The burnout apparently started immediately

to the right of the joint, at a point inside of the split vitrified tile, and burned towards the right into the conduit. (There was no trouble whatever on any of these cables to the left of the joints.) The street had a perceptible grade downward to the right, and the conduit being approximately parallel to the surface of the street, had a sufficient grade so that the melted copper and lead from the burning of the cable in the duct ran along in the conduit beyond the burn. There was one large cable in each of the nine ducts in the conduit, and the cable which was the most badly injured, and which apparently was the cause of the trouble, was in the middle duct of the outer vertical row. When we were able to get into the man-hole, we found that the cable ended at the point just to the right of the joint where the trouble had apparently started. The rest of the



cable had disappeared except for some stalagmites of lead and copper in the bottom of the manhole. This was a 1,000,000 c. m. concentric cable, carrying low tension direct current at approximately 230 volts. We saw that all of the cables in this part of the manhole, as well as those on the side of the manhole opposite from that shown in the picture, had been badly burned by the action of the arcs from the several cables. Two similar concentric cables on the other side of the manhole had also burned in two, but careful consideration of all of the facts in the case leads us to believe that the cable indicated in the drawing was the one on which the trouble started; it was without any doubt the one which was the most badly injured. In the high tension cables in the ducts immediately above and immediately below this concentric cable, all of the lead had melted and the paper insulation was so badly burned that it could be easily knocked off with a stick. These latter cables were high tension

cables protected by automatic switches, and therefore, they could not maintain an arc for more than one second. The condition of the high tension cables indicated that all of the damage had been caused by the arc from the low tension cables, so that the heat which melted the lead from the high tension cables and charred their paper insulation, was conducted through two layers of split vitrified tile. Most of the split tile protecting the cables was still in position when we entered the manhole, and we could not accurately determine the condition of the cables until these tile coverings had been removed. As there were nine cables which had to be replaced, and their average cost was something like the figure which Mr. Lake gave in the paper, namely, \$1.25 or \$1.50 per foot, we were much interested to know whether and how far the cables were injured in the conduit; that is, to determine whether we would have to replace the entire length of cable to the next manhole, or whether the cables were only burned back into the duct a few inches, so that it would be sufficient to enlarge the manhole, cut off the cables beyond the point where they had been injured, and splice on new sections a few feet in length. To settle this point we immediately made an excavation alongside of the manhole and exposed the 10 feet of conduit adjacent to the manhole. At the time that we had the conduit exposed, the manhole was still so hot that we were unable to do any work on the cables, and as the burned ends of the cables were hanging down in an irregular manner we had not noted that there was one cable for each of the nine ducts in this conduit section. As soon as the conduit was exposed, the foreman in charge of the work, who was a man of many years experience in the business, got down into the trench and personally broke into the concrete ducts forming the conduit, so as to determine the extent of injury to the cables. The top duct of the outer vertical row was first broken into with a hammer, and the cable therein was found to be uninjured in any way except for about an inch immediately adjacent to the manhole. The foreman then broke out the next duct, and finding nothing in it, put his hand into the duct, running it back and forth to feel the condition of the duct; upon doing so he immediately said: "That duct is vacant, there is no cable in that duct at all." He then broke away the next duct in the lower row and found it was occupied by a cable which was in excellent condition. To check the foreman's statement that the middle duct was vacant, men were sent to the next manhole and found that there was a 1,000,000 c. m. concentric cable in the duct which had been declared vacant. We thereupon made a more careful examination of the pieces of the concrete pipe which had been thrown out of the trench, and broke off more pieces of the so-called vacant duct. We found by this examination that the concrete, although almost as smooth on the inside as new concrete pipe, showed perceptible signs of burning for nearly  $\frac{1}{4}$  in., and that the surface material was inert, that is, friable and easily removed, like lime. The remaining portion

of the concrete pipe, comprising about three-quarters of the total thickness of the pipe, appeared to be just as good and strong as it ever had been. We have here, therefore, a direct comparison between the arc-resisting and heat-conducting properties of the vitrified clay tile around the cables in the manhole, and the concrete pipe surrounding the cables in the conduit. It is the same cable, and the current in the arc was fed from the same source throughout the trouble. The cable burned for about 25 feet into the conduit before it was disconnected, and although there was considerable flame in the manhole, due to the burning of the gases from the resinous material in the paper insulated cable, the arc was at a considerably higher temperature than this gaseous flame, and the heat from the arc was conducted through two layers of tile in the manhole so as to melt the lead off of the cables in the adjacent ducts, while it failed to injure in any way the lead or the insulation of the cable in the concrete pipe of the conduit. The tile conduit in the manhole also showed, on its interior surface, greater signs of injury from the direct action of the arc than did the concrete pipe in the conduit.

Mr. Lake spoke of the desirability of getting vitrified clay which is free from moisture, because of the difficulties which would be caused by an arc or other sources of heat in the duct or in the conduit construction. This freedom from moisture is also desirable from the opposite point of view—that is, in the case of the freezing of the ground. We had a case some years ago where the ducts were laid, as most of our conduits are, within freezing depth—that is 30 inches more or less, of the surface of the street—and these ducts had a high percentage of absorption. Some years later, on account of the city building a sewer along that street, we had to move several blocks of that conduit, which gave an excellent chance to examine it. We found that this particular conduit was so badly broken that it could not be handled; there were a series of fractures running all through the tile like crackle ware. It apparently had been ruptured by freezing, and although it had not so broken that it collapsed and filled up the hole, it showed that the structure was considerably weakened and might have caused trouble later.

A section is shown in Fig. 13 with the ducts laid in horizontal rows separated by an inch of concrete, which the speaker called a single duct laid in tiers. It is very difficult to secure uniform thickness in spreading a single layer of concrete, and to keep the ducts in alignment after they are laid. After the trench is excavated, three inches of concrete is laid on the bottom, then a layer of ducts, then one inch of concrete and another layer of ducts; but the workmen will walk on this latter layer of tile resting on an inch of concrete which has not set, with apparently nothing to hold the ducts in alignment except gravity and the friction on the concrete. The result is that with that kind of construction, instead of getting the expected  $3\frac{1}{2}$  in. of opening, it is found that, in attempting to pull a 3 in. mandrel through, it cannot be done; in fact, it is sometimes

difficult to get a  $2\frac{1}{2}$  in. mandrel through. The question of alignment is one of the hardest problems in the single duct tile construction, and our experience is that we have less difficulty drawing our cables into  $3\frac{1}{4}$  in. round section concrete pipe, which is in more accurate alignment, than we have in  $3\frac{1}{2}$  in. square bore vitrified tile.

Occasionally we have had difficulty in drawing cables into the tile ducts, and the foremen have brought sections of such cables into the office which looked as if they had a square section; that is, the ducts would be offset in one place so that the cable would be squeezed and flattened, and in another place the cable would twist or the alignment would be offset in the other direction, resulting in a section that looks like a square cable with rounded corners—not  $3\frac{1}{2}$  in. square, but something much smaller than that— $2\frac{1}{2}$  in. or thereabouts.

The statement was also made that the square section offers less resistance when two or more cables are being drawn in. That is the reverse of our experience. The men on the ground who have actual charge of installing these cables say that the large cables, from 2 in. to  $2\frac{3}{4}$  in., are drawn into the ducts with apparently less friction with the square section than with the round section, their theory being that the arc of contact with the cable and the duct is less when the cable rests on a flat surface than when it rests on the inside of a cylindrical surface. I am speaking in both cases, of course, of conduit section in which one meets with no difficulty like the offset ducts that I spoke about a few minutes ago. Where we have two or three or four single cables pulled into one duct, however, the cables apparently assemble so that they fill the larger portion of the duct, but they become wedged in there, and then as the pulling rope turns—and it always does unwind somewhat as the strain is applied—that twists the grip which is fastened to the cable and twists the cable in the duct. When this twisting action occurs, these cables have to move on each other and assume a new relation with respect to each other. That does not occur where we have a round duct construction, and where the cables can twist in the duct and always hold the same position with respect to each other.

In the illustrations showing the laterals there were several suggestions, one of which included a fiber duct or pipe, surrounded by iron pipe. As I read the picture, however, it appeared that these lined iron pipes were all intended for small cables like the single comparatively small cable that was shown in the laterals. That appears to be an excellent idea, but I should be glad to see how to apply this idea practically to a case where it is desired to pull four cables into the lateral, and the cables nearly fill a 3 in. round pipe. That means that you have to maintain a 3 or  $3\frac{1}{2}$  in. section throughout the length of the lateral instead of having it  $2\frac{1}{2}$  or  $2\frac{1}{4}$  in. through part of the lateral.

Among the suggestions was one which included a square con-

duit for certain kinds of cable, and a round bore for certain varieties of cable. The difficulty I have found in laying out conduit lines is to tell just what particular duct in the conduit is going to be used for high tension, and which for low tension or some other variety. It is very difficult indeed for us to tell in which section of the city our growth is going to be, where the next large customer is to be located, and what kind of current he will want. We even find considerable difficulty in determining, with any degree of accuracy, the size of conduits—that is, the number of ducts that we should install in some particular street. I remember one case where we did not have a conduit within several miles, but as one of our friends was building one and asked us to build a joint conduit, we took a chance and asked him to build three ducts for us, although we had no conduit within two miles of it. Within three years we had to install four additional conduits in that street, so that we had seven ducts where we thought three were enough to last us five or ten years.

The speaker, in referring to single duct tile, did not bring out one of its good points, which is one of its most valuable assets for conduit work, and that is the ease with which a tile conduit line can be broken out and repaired. We frequently have a case of trouble, either real or fancied, where we have to, or do, dig up the conduit line to repair or to examine the cables. In some cases we have to break out the conduit to allow the installation of a water pipe or a sewer or something of that sort. With some of the multiple duct sections, the replacement is very difficult and almost impossible without first removing the cables. With the single duct vitrified tile, however, you can, by the aid of split tile, lay the same identical conduit section around the cables which are already in the conduit, and then lay the standard single duct straight tile for the rest of the ducts.

*Prof. Woodworth:* Are we to infer that in your opinion concrete tile has a better heat-resisting value than the regular vitrified tile?

*Mr. Roper:* Yes, sir.

*Mr. W. B. Jackson, M. W. S. E.:* I wish to ask Mr. Roper if it is the custom of his company to carry out three or more cables from a single lateral? He spoke of that as being one objection to the lateral shown by Mr. Lake.

*Mr. Roper:* We frequently install several cables in one lateral; they are comparatively small, however; for instance, in our low tension work we install three No. 6, three No. 0, or three No. 0000 cables in one lateral. If those three cables occupy one duct in the conduit, we continue the whole construction and put the three cables in one lateral pipe up the pole. In our sixty cycle work we follow the same practice, and install as many as four No. 6 or four No. 0 cables in one lateral pipe up the pole, which is the same construction that we have in the conduit.

*Prof. Woodworth:* Mr. Baird, of the McRoy Company, is asked for his opinion as a representative of a conduit company.

*Mr. C. A. Baird,* (McRoy Clay Works): I have listened with a great deal of interest to the various talks, and there seems to be a difference of opinion on the part of engineers. I think I can safely say that the manufacturers of clay conduits are all of one opinion, that is, that of course they manufacture the best conduit there is.

Referring to the point which Mr. Roper made in showing the manhole with the burnout. Would the conditions have been changed if the concrete had been used in the manhole to encase the joint of the cable and the tile leading back underground? That is, would not the same result have been obtained?

*Mr. Roper:* Replying directly to Mr. Baird's question, I will state that, judging from our experience in similar cases of burnouts on concentric cable connected to our low tension system, if the duct material in the conduit had been vitrified clay tile, this tile would have been partly melted by the arc, and the cables in the adjacent ducts would have been quite appreciably injured. We have had several cases of trouble of this kind where the burning of a concentric cable in a tile conduit has melted the tile and injured cables in adjacent ducts.

*Mr. F. W. Darling* (Clay Product Co.): I appreciate very much the invitation given me to come here tonight. Mr. Lake mentioned the round bore single clay conduit. It is true that in the manufacture of conduit the round single ducts require considerably less care. Suppose that we have rejections, that is, cull out in the manufacture of square single tile, 10% of them; in the round single ducts we can cut the amount down to almost 2%. If there is that difference in the manufacture of the tile, there would naturally be that difference in the cost of the two. This is probably due to the fact that in burning the round single duct, having a sort of arch construction although of clay, it does not give way under the strain of manufacture and burning as the broad side of the square duct does. Also, it is reinforced by the extra thicknesses of clay on several corners instead of having a flat side and equally thick corners.

In regard to the voids in connection with the square duct. After Mr. Lake sent us that letter asking for information relative to manufacturing the square tile with a very small radius on the outside corners, we attempted to make some, using an old die and filing out the corners. We found that such tile could be easily made, but that if the clay is run stiff and thick, requiring but a short time in the dry room and thus reducing the cost, it roughs up or scales on the corners. That does not injure the tile, however; the outside is simply roughened up, with a little peeling and scaling. The inside remains perfectly smooth. Of course, the inspectors might infer that those cracks went through.

A well vitrified clay conduit, in its manufacture, is burned to a temperature of approximately 3,000°. It is supposed to stand a

temperature of about  $4,000^{\circ}$  before giving way. Under usual and ordinary circumstances, cement products cannot stand a temperature of over  $1,800^{\circ}$  without having the lime salts broken up and dissipated, reducing the cement mass to a condition about as friable as soft plaster. With this in mind, it seems hardly fair to accept the single instance which Mr. Roper mentioned as a proof of the test. It seems as if we ought to be able to find another reason for the destruction of the cables in the manhole while they maintained their contact in the duct lines. It occurs to me that an explanation may be found from the fact that the duct lines had a gradient up to the point where the burnout occurred. This being true, the instant the temperature was raised at the point of burnout a draft would be generated from the conduit line towards the manhole. As the burnout extended along the cable, the path of the draft being determined previously, this current of cool air would doubtless increase considerably and carry the heat out of the duct, acting as a flue. That this was true to a certain extent is shown by the fact that the residue from the burnout was found in the manhole, and a further proof would be that adjacent cables in the manhole were burned inside of the clay conduit by the prolonged temperature thus maintained. I am, in fact, surprised that the clay conduit in the manholes did not give way under the temperature thus produced. It is, of course, admittedly important, with our present knowledge, to get a substance for conduit which will be practical, and yet withstand the terrific temperature produced by a burnout, but the tests which we have made, comparing vitrified clay conduit with cement and fiber products, show conclusively that the clay conduit will withstand temperatures varying from  $1,000^{\circ}$  to  $2,000^{\circ}$  higher than either of the other substances.

*Mr. George B. Springer, M. W. S. E.:* I do not want to bring Mr. Lake to tears, but he spoke of laying conduit in tiers, that is, separating it by one inch of concrete. While 1c a duct foot does not seem to be a very large figure for one duct foot, it occurred to me, when I looked at some of his sections there, that when you come to install say 2,000,000 duct feet it is a matter of \$20,000, and I have some doubts as to whether the excess cable trouble which we might experience in a year, directly traceable to the voids in laying conduit, would approximate anything like \$20,000. Therefore I think that one inch of concrete between the ducts would not be advisable from the standpoint of economy, and having a structure which is good enough for the purpose. In other words, I do not think that the expenditure would be justified.

*Mr. Lake:* It should be remembered, in considering these suggested improvements, that some of us are looking at the problem from the standpoint of railway distribution, and others from the standpoint of the Commonwealth-Edison, large lighting and power company. This may account for some of the differences of opinion which have been expressed.

I will ask Mr. Roper if the burnout referred to is what is called a "slow burn" or one which started from a short circuit, and was sudden and vicious in its action?

*Mr. Roper:* As near as I can recall the matter, it took something like half an hour to burn the 25 or 30 feet of cable, or it may have been 45 minutes before the cable was entirely disconnected. (I might say that concentric cable burning that way does not burn at all rapidly.) I watched the cable burning while the men disconnected it from the underground mains in another manhole; it burns much like a fuse would burn, with a fairly continuous arc, illuminated now and then with a burst of flame.

*Mr. Lake:* Was there a steel shelf in the manhole?

*Mr. Roper:* Yes, there was.

*Mr. Lake:* Just one more question, Mr. Roper—were the cement ducts separated by concrete?

*Mr. Roper:* There was an inch of concrete between ducts.

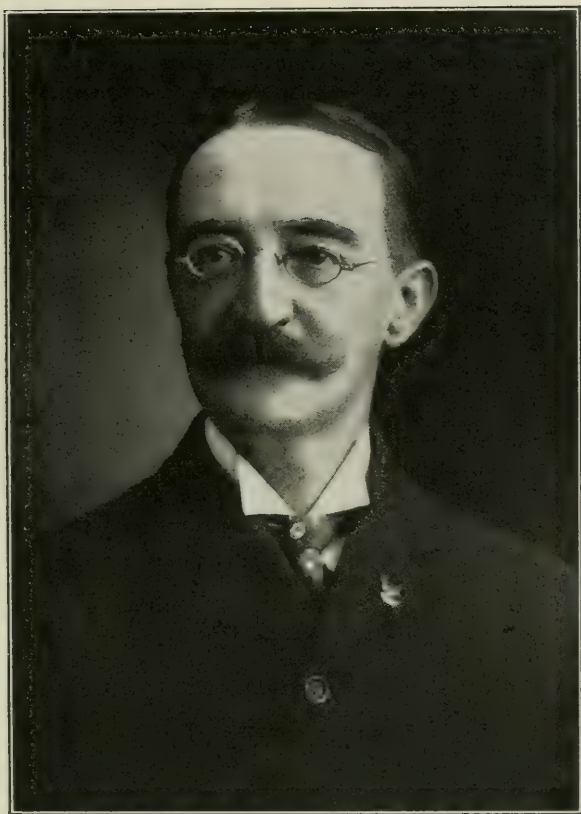
*Mr. Lake:* One inch of concrete on all sides? That is, the ducts were really laid in horizontal tiers?

*Mr. Roper:* Yes.

*Mr. Lake:* The matter of concentric cable burnouts is something that is unfamiliar to those of us who are interested in street railway distribution here in Chicago. I am inclined to agree, however, with Mr. Baird, that the results might have been the same if the burnout had occurred in a vitrified clay duct. At any rate, the one inch of concrete between the cement pipe is certainly a desirable feature.

The matter of laterals which we use in street railroad work and the size of cable is confined almost entirely to 100,000 and 500,000 c. m., ordinarily; 350,000 c. m. is also largely used. Those are the three sizes of single cable which would be used in the construction of laterals. It is possible, however, to secure fiber in the larger sizes, and of course, possible to secure the iron pipe to protect the fiber up the pole of any size which might be desired. Fiber can be obtained of any size up to 8 or 12 inches, but I believe the latter is the limit that is manufactured at the present time. Four inch pipe and its lining would be thoroughly practicable, and the lining would not have to be very thick.

## IN MEMORIAM.



CHARLES FREDERICK FOSTER

Born Boston, Mass., September 28th, 1852,

Died Chicago, Ill., May 8th, 1910.

At rest Salem, Mass., May 14th, 1910.

Thus endeth the record.

We bow our heads and mourn for a fellow member whose integrity and steadfast purpose in life were for the benefit of his fellow man. Calm, courteous, resourceful, never vacillating, always accessible, fearless and brave, this splendid exponent of our profession was a noble and lovable character.

Like the setting of the sun in the desert, when it sinks to rest quickly, but leaves a momentary glow before the blackness of night settles o'er the parching sands, so was the closing moments of his life; death came quickly; there was no lingering sickness. Cerebral hemorrhage, probably caused from over study and too close application to his chosen vocation, is said to have been the

June, 1910

immediate cause of his demise; a peaceful ending after a long and active career, in which he had been identified with many of the greatest engineering undertakings of the latter part of the nineteenth and the beginning of the twentieth centuries.

Charles Frederick Foster was the second son of Homer Foster and Mary Joanna Dudley Foster, and was of sturdy New England stock. At the early age of four he entered the Suffolk Primary School of Boston, passing from thence to the Brimmer Grammar School. He was a member of the second division of the first class and one of eight diploma boys the last year, but was unable to graduate as his parents moved from the city about 1864. He next entered the Punchard Free School of Andover, Mass., from which he graduated in 1869.

At the age of sixteen and one-half years he commenced his engineering career as a rodman; later he became leveler and transitman in the office of the City Engineer of Boston, Mass. He was connected with the Engineering Department of the city until 1872.

The next two years was spent as transitman on the Lowell and Andover Railroad in Massachusetts and as assistant to Fred R. Page, surveyor and engineer at Lowell, Mass.

In 1874 and 1875 he was employed in various capacities as rodman, transitman and Assistant Engineer on the Engineering Corps building the City Waterworks at Lawrence, Mass.

Subsequent to this he became Assistant Engineer to Mr. Walter McConnell, in general engineering work in Boston and surrounding cities and towns.

From 1876 to 1880 he occupied the position of Mechanical Engineer and Assistant Manager of the Manchester Mills at Manchester, N. H.

In 1880 he removed to St. Louis, Mo., and became the General Superintendent of the St. Louis Cotton Mills, which position he held until 1883; when he resigned to become the Vice-President and General Manager of the Heine Safety Boiler Co. of St. Louis, Mo., and continued in this capacity until 1892.

The closing months of this year found the work in the Mechanical and Electrical Departments of the World's Columbian Exposition in such a state of incompleteness that the Director of Works questioned the ability of the exposition to complete the construction work before the opening date, May 1st, 1893. It was then that Mr. Foster was appointed Assistant Mechanical Engineer. In February, 1893, the two departments were separated, and he became the Chief Mechanical Engineer, carrying the work through to completion on time, and then assuming the duties of operating the power and water plant during the progress of the exposition, in a manner which called forth the commendation and praise of his superiors and the love of his fellow associates.

For his work at the exposition he received a number of

medals and complimentary letters. Not the least of the latter is one from the then Director of Works, in which he stated the following: "In the middle of February, 1893, the mechanical plant of the Exposition was not half done. It looked like an impossibility to get the work ready and open the fair. Mr. Charles F. Foster was put in charge. He shouldered the job and carried it through in fine shape to the end of the exposition. There is no man his equal that I know of to install and operate great mechanical plants in quick time and with economy and I do not believe there is any one in the country who can beat him designing. He is a remarkable man in every respect."

The two years following the fair were devoted to private practice as a Consulting Engineer in Chicago, when he became identified with the Cotton States and International Exposition at Atlanta, Ga., in the capacity of Mechanical and Electrical Engineer, and carried this enterprise to a successful termination. He received a number of medals in recognition of his ability at this exposition, after which he returned to Chicago and again assumed his private practice as a Consulting Engineer.

In 1904 he identified himself with the Universal Exposition at St. Louis, Mo., in the capacity of Chief Operating Engineer, which position he creditably filled until the close of the exposition in November, 1904. For this work he received a number of medals and a diploma of honorable mention, together with many complimentary letters from prominent officials associated with the undertaking.

In January, 1905, he returned to Chicago and again resumed his private practice, devoting not an inconsiderable amount of his spare time through the day and practically all his evenings to the compilation of engineering data. These data were to be published in such a form that many of the complex formulas connected with the mechanical and electrical profession would be set forth in exhaustive tables, thereby eliminating in a great measure the necessity of their computation. The regret is that his sudden demise leaves the work in an incomplete condition and not ready for publication, as it bid fair to be a valuable acquisition to the technical literature of the profession.

Mr. Foster in 1877 married Miss Kate Cook at Andover, Mass. There were no children by this marriage.

He was a prominent member of the Independent Order of Odd Fellows, and rose through the several graduations of the Order until he attained the rank of Colonel and Assistant Adjutant General on the Department Commander Staff of the Department of Illinois.

He was a member of the American Society of Mechanical Engineers, Western Society of Engineers, and Engineers' Club of St. Louis.

Mr. Foster will be best remembered for his wonderful power of thought concentration; his indomitable energy; his deductive

mind; his mastery of detail; his executive ability; his skill in handling large bodies of men and moulding them into a concrete, harmonious, forceful, working unit; his connection with various Universal Expositions, to which reference has already been made; and by his intimates for his amiable disposition and lovable character.

Clayton O. Billow, E. C. Shankland,  
Wm. S. Monroe,  
Committee.

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### SAMUEL W. McMUNN.

The subject of this sketch, an Associate Member of the Western Society of Engineers since December 6th, 1902, died April 29th, 1910, at his residence, 5423 East End avenue, Chicago.

He was of Scotch ancestry on his father's side, and of Irish on that of his mother, and was born at Sharon, Noble County, Ohio, on March 20th, 1850. He received his education in the common schools of Sharon and at its academy, which fitted him to become a teacher. This occupation he followed immediately upon his graduation, until a desire to branch out into the more energetic activities of business life induced him to seek and obtain employment with the Ohio River Salt Company at St. Louis. His ability soon won him a partnership with G. L. Joy & Co., when they became the successors of the Ohio River Salt Company. Shortly after Mr. McMunn was, in addition, made president of the American Transportation Company, and also president of the American Brake Company, which company owned the original patents for locomotive air brake equipment.

In 1884 Mr. McMunn changed his quarters to New York City to become manager of the Consolidated Coupling Company, in which position he developed the early stages of the automatic coupler, now universally used in this country. He was later connected with the Carnegie Steel Company in Pittsburgh, and the Otis Steel Company in Chicago. The development of appliances and devices useful to the public generally and to the engineering profession in particular always had a strong attraction for him, and many of the improved appliances in use today owe their existence primarily to his effort. Notable among these may be mentioned the United States Steel Sheet Piling, the Raymond Concrete Piling and the Kindl Car Truck, which was perhaps the most prominent of the earlier types of steel truck frames. Of late years Mr. McMunn has devoted himself principally to the development of The Brown Process Company, a corporation owning valuable patents for the conservation of fine ores. He was president of this company from its inception until his death.

At the time of his death Mr. McMunn was a member of the Western Society of Engineers, the Engineers' Club of New York, the Machinery Club of New York, the Duquesne Club of Pittsburgh, and the Union League, Hamilton, Chicago Athletic, Illinois Athletic and Calumet clubs of Chicago.

# PROCEEDINGS OF THE SOCIETY.

## ABSTRACT OF THE MINUTES OF THE MEETINGS.

*Wednesday Evening, May 4, 1910.*—Regular meeting (No. 700) of the society, called to order at 8:30 p. m., Vice President Bement presiding and about thirty-five members and guests in attendance. Minutes of meetings, April 6th and 20th, read and approved. Reported from the board of direction the election as active members of:

Roy H. Slocum, Fargo, N. D.

Irvin L. Simmons, Chicago.

Applications for membership received from:

George W. Horn, of Chicago.

Winfred Kallasch, of Chicago.

Grant Ford, of Chicago.

Report from committee appointed to consider what action should be taken by the Society on certain bills pending before Congress, relating to the Corps of Engineers and the status of civilian engineers engaged therewith on River and Harbor work, was presented with resolutions against action on H. R. 7117, but recommending action on H. R. 10029. This was voted down by the Society.

The death of S. W. McMunn, Assoc. M. W. S. E., April 30th, was announced.

Mr. R. Y. Williams, M. W. S. E., was introduced, who presented his paper (which had been printed in advance) on Rescue Stations in Illinois Coal Mining Localities. Discussion followed from Messrs. F. W. DeWolf, F. D. Chadwick, J. E. Hitt, E. C. Lewis, J. E. Ford, and J. F. Hayford, with a closure by Mr. Williams. Adjourned at 11 p. m.

*Wednesday Evening, May 11th.*—Extra meeting (No. 701) of Bridge and Structural Section, called to order at 8:20 p. m., with Mr. T. L. Condron, Chairman, and about seventy members and guests in attendance. Mr. J. H. Prior, M. W. S. E., was introduced, who read his paper on the C., M. & St. P. Ry. bridge at Mobridge, S. D., with stereopticon illustrations. Discussion followed from Messrs. W. C. Armstrong, G. E. Tebbetts, W. H. Alderson, H. E. Vanderlip, J. Gibson, C. R. Dart, F. G. Vent, W. L. Cowles, E. H. Lawrence, and the chairman. Adjourned at 10 p. m.

*Wednesday Evening, May 18th.*—Extra meeting (No. 702), called to order at 8:25 p. m., with Vice President Bennett presiding and about twenty-five members and guests present. The death of Charles F. Foster, M. W. S. E., May 8th, was announced. Mr. Jean Bart Balcomb was introduced, who presented in abstract his paper (printed in advance), "The Design of Storm Water Drains in a Modern Sewer System." Discussion followed from Messrs. C. D. Hill, L. K. Sherman, W. M. McCartney, W. W. Deberard, the Chairman, with a closure from the author. A vote of thanks was tendered Mr. Balcomb for his paper. Adjourned at 10 p. m.

*Friday Evening, May 27th.*—Special extra meeting (No. 703), called to order at 8:25 p. m., with Vice President Bement in the chair and about forty-five members and guests in attendance. Prof. A. H. Sabin, of New York, was introduced, who addressed the meeting on paints and pigments, particularly white lead and its manufacture, with stereopticon illustrations. Discussion from Messrs. P. Junkersfeld, M. H. Dance, E. N. Layfield, J. F. Werlich, E. McCullough, F. E. Dodge, B. G. Jamieson, Wm. Artingstall, W. T. Brennan, C. R. Dart, W. S. Barrett, G. H. Boyd, C. H. Rose, G. A. Tinker, C. K. Mohler, F. P. Kellogg, J. H. Warder, H. J. Wagner, the Chairman, and a closure from Prof. Sabin, to whom a vote of thanks was tendered. Adjourned 10:45 p. m.

J. H. WARDER, Secretary.

## BOOK REVIEWS.

**THE FIELD PRACTICE OF RAILWAY LOCATION.** By Willard Beahan. Engineering News, New York. Cloth,  $5\frac{1}{2}$  by 9 ins.; pp. 252, including index. Price, \$3.00.

The first edition of this work placed in definite form the results of thirty years of experience on the part of locating engineers. During this period a new branch of civil engineering was developed—one depending less on theory than on accumulated experience. The present high state of this branch of civil engineering is due to the patient work of locating engineers in developing methods for applying sound economic principles to railroad location. In his preface, the author states that it is his purpose to record these methods before the men that developed them have passed away.

The economic units and principles are those of Wellington. This is necessarily the case, since Wellington has come to hold somewhat the same place in railroad location that Blackstone holds in the law. Like Blackstone, Wellington is rather too voluminous for every-day use, and somewhat out of date, perhaps, but the work contains fundamental principles on which all future development must be based. Hence, the value of this compact work, containing, as it does, about as much of the economic theory as the practicing engineer is ever likely to need.

The details of conducting surveys in the field are not so exhaustively treated as in some works, but sufficiently so to meet the needs of the man in responsible charge of railroad location. Apparently the work is designed primarily for the man in responsible charge, and not for the detail worker. The subjects that the chief of party needs to know are well covered in chapters relating to reconnaissance, organization of parties, preliminary surveys, and located line. But the work goes much further than this. The chapter devoted to "Character of Road" would seem to be the concern of the president and board of directors of a company rather than the engineer; while the discussion of the locomotive, and cost and capitalization fall rather within the province of the chief engineer.

Owing to the intimate relation of topography to geological structure, there is included in the book a chapter prepared by John C. Brannar, entitled "Geology in Its Relation to Topography." Throughout the book, in fact, much attention is given to this subject of topography, as being one of the most important matters with which the locating engineer is concerned. The chapter on reconnaissance is a particularly important one. Thorough instructions are given as to methods of carrying on this work. The investigation of country by means of a multiplicity of preliminary lines is justly condemned.

Any engineer having to do with railroad location will find much of value in this book. But its greatest value lies in the discussion of matters of importance to the engineer or railroad officer in responsible charge.

E. J. M.

**THE PRINCIPLES AND PRACTICE OF IRONFOUNDING.** By E. L. Rhead, Lecturer in Metallurgy, Municipal School of Technology, Manchester, England. The Scientific Publishing Co., Manchester, England.  $5\frac{3}{4}$  by  $8\frac{3}{4}$  ins.; pp. 505; 247 illustrations; cloth bound. Price, 7s, 6d (\$3.00).

This is an interesting and valuable book to the engineer as well as the technician engaged in foundry work. Even experienced foundrymen in well established and successful foundry practice should find some matters in this book to their advantage.

Beginning with a study of the ferrous metallic compounds suitable for making castings, which constitutes the first chapter of sixty-four pages, the author then considers the Testing of Cast Iron, which includes not only the strength and elasticity but also the characteristics of fluidity when melted, the shrinkage when cooling, the property of hardening by chilling, etc. Next of importance to the metal that is to be melted and poured into moulds for manufacture of the desired object, is the moulds in which the metal is cast. This is treated in Chapter III, which describes the necessary characteristics of good moulding material, the preparation of the moulds, etc. Supplemental

to this comes a consideration of the machinery and appliances for the preparation of the moulding materials, followed by Chapter V on Facing Materials, the proper use of which is so necessary in securing good and handsome iron castings. Such materials are necessarily of various substances and applications, depending upon the character of the moulds and the object to be made. In natural sequence come subsequent chapters on the moulding tools and appliances, including flasks, rammers, etc. Foundry Moulds and Their Production, and Moulding Operations (this latter occupying three chapters of nearly sixty pages), follows. As an adjunct to the preceding is Chapter XI on Cores and Core-Making, in which great improvements have been effected and machinery introduced within a comparatively recent time.

A matter of considerable magnitude and importance in some foundry work is Loam Moulding, which is treated in Chapter XII, of over forty pages. Of recent years and since the reviewer rammed up his daily stint on the floor, has been the advent and successful introduction of moulding machinery, the use of which resulted in cheaper and more uniform product. This naturally applies to such cases as the manufacture of many castings of the same size and character. One of the specialties in foundry work is that of Chill Castings, which is the subject of Chapter XIV. The next chapter considers the opposite, that of Malleable Castings, in which the metal of selected chemical character, after being cast into the desired object, is changed in its physical character by annealing, making the casting softer and more tough. Such castings are of great importance in many lines of manufacture, notably that of agricultural machinery. The melting of the iron with which the moulds are to be filled is of great importance, as the value of the casting, as such, is very dependent upon the melting of the metal, and the profits of the foundry depend upon this being done with economy. This subject is treated of in Chapter XVI, and following are Cupolas, with their adjunct of Fans and Blowers, and also Air Furnaces with their modifications and adaptations. An appendix of a dozen pages, containing some useful data, Notes on Pyrometers, etc., completes a valuable manual on this subject of Iron Founding. W.

**PRACTICAL ALTERNATING CURRENTS AND ALTERNATING CURRENT TESTING.** By Charles F. Smith, M. Sc. Tech.; M. I. E. E.; Assoc. M. Inst. C. E.; Whit.-Schol. Third edition, revised and enlarged. Cloth,  $5\frac{1}{2} \times 8\frac{1}{2}$  ins.; pp. 455. Price, 6s net. The Scientific Publishing Company, Manchester, England.

The opening chapters of the book deal with the general laws of alternating currents from an elementary standpoint. The various subjects are taken up in logical order and explained by graphical methods in a clear and concise manner. No knowledge of alternating currents is presumed, and the use of higher mathematics is carefully avoided throughout the book.

After the discussion of the general laws, the following subjects are taken up and treated in detail by graphical methods: The Transformer, 64 pages; Alternators, 59 pages; Synchronous Motors, 25 pages; The Polyphase Induction Motor, 76 pages; Single Phase Motor, 34 pages; and the Composition of Waves, 28 pages. The treatment of each of these subjects is excellent, modern methods being used throughout. In the chapters dealing with the induction motors, the Heyland circle diagram is explained and made use of, and experimental methods for obtaining the diagram are given. The chapter on the composition of waves gives methods and examples of analysis of alternating current wave forms into the fundamental sine wave and its harmonics.

The book contains, besides the explanations, forty-eight experiments illustrating various phases of the subject, together with numerous curves and examples determined from actual tests. The value of the book is still further enhanced by diagrams of connections required for the experiments and detailed directions concerning the same.

The work would make an excellent laboratory manual for colleges of engineering, and should be of great value not only to students but to electrical engineers in general. For clearness of exposition and conciseness, the book cannot be surpassed and should appeal to all interested in the subject of alternating currents. F. A. R.

TABLES AND DIAGRAMS FOR OBTAINING THE RESISTING MOMENTS OF ECCENTRIC RIVETED CONNECTIONS. By E. A. Rexford. Engineering News, New York. Boards, 8 by 10 ins.; pp. 30. Price, \$1.00 net.

Two sets of forces are to be considered in the determination of the value of an eccentric connection: First, the vertical shear, which is equally divided among all the rivets. Second, the moment around the center of gravity of all the resisting rivets, and which acts perpendicular to a line connecting the extreme rivet to this center of gravity. The resistance value to bending of any group of rivets of fixed spacing may be expressed by a coefficient.

Plate I gives these coefficients for spacing of rivets of  $2\frac{1}{2}$  to 6 in., in a single vertical row of two to twenty rivets. These coefficients are correct. For this condition the forces resisting bending would be perpendicular to those resisting shear, as the row of rivets is vertical. So we have a diagram of perpendicular coördinates given in connection with this table, on which is shown a number of arcs of circles representing the value of standard rivets in bearing and shear.

Assuming some groups of rivets for a particular case, we divide the total shear by the number of rivets, which gives the shear per rivet. We next divide the bending moment in inch pounds by the coefficient, which gives the stress in the extreme rivets due to bending. By plotting and shearing stress vertically on the diagram, and the bending stress horizontally, the distance from the origin to the intersection of the coördinates represents the total stress in the extreme rivets. The connection is right if the intersections fall on the arc representing the value of rivet being used.

Following Plate I, diagrams and coefficients are given for: Two rows of rivets,  $2\frac{1}{4}$  in. centers up to twenty rivets per row; two rows of rivets 3 in. centers up to eight rivets per row, where the difference between 3 and  $2\frac{1}{4}$  in. centers is slight; two rows of rivets  $5\frac{1}{4}$  in. centers up to twenty rivets per row; three rows of rivets spaced  $2\frac{1}{4}$  and  $5\frac{1}{4}$  in. centers up to twenty rivets per row; four rows of rivets with  $2\frac{1}{4}$ ,  $5\frac{1}{4}$ ,  $2\frac{1}{4}$  in. spacing up to twenty rivets per row; two rows of rivets  $2\frac{1}{2}$  in. centers, up to sixteen rivets per row; the vertical spacing of all the foregoing being 3 in. centers; four rows of rivets spaced  $2\frac{1}{8}$ ,  $5\frac{1}{2}$ ,  $2\frac{1}{8}$ , up to thirty-four rivets per connection but spaced alternately  $1\frac{1}{2}$  in. vertically.

The coefficients given are correct within one-tenth, as many of them were verified; though given to hundredths, they evidently had been calculated to tenths only. The connections given cover a great many cases and the method used to determine the resisting moment is simple and direct. For those who must design such connections the book would be a great help.

J. G.

BRIDGE AND STRUCTURAL DESIGN. By W. Chase Thomson, Mem. Can. Soc. C. E., and Asst. Eng., Dominion Bridge Company, Montreal, Canada. Engineering News, New York, 1910. Cloth;  $6\frac{1}{2}$  by  $9\frac{1}{2}$  ins.; pp. 192; illustrated. Price, \$2.00.

This is the second edition of this book; the first edition, published in 1905, has been entirely rewritten and much new material has been added.

Chapter I gives definitions and explanations of terms used and also presents graphical treatments of a number of roof trusses, and the theory or moments.

Chapter II deals with the shearing and bending stresses in beams. Chapter III is devoted entirely to the deflection of different types of beams, and Chapter IV treats of columns and struts. The remaining Chapters, V to XII, deal with the design of various types of structures ranging from office and mill buildings to highway bridges.

The book has evidently been written with great care. The theoretical part is presented in a sufficiently simple manner to make it easily understood by men who have not had the advantage of a technical education, and examples are given of how the different theories are applied in practice.

In the chapters treating on the design of complete structures, the writer finds some assumptions with which he cannot agree. For instance, he would consider that, for wind, a pressure of 30 lb. per sq. ft. of vertical plane surface is about 50% too high. It is extremely improbable that high wind

pressures will ever occur at a time when any structure is subjected to maximum live loads.

The subjects for design are all practically chosen, and while they necessarily serve to bring out but few of the many problems which confront the designer, they do present the general ideas and methods of design in a satisfactory manner.

The author states that the book is intended principally for students and draftsmen. The writer considers it a valuable addition to any engineering library.

W. S. M.

## LIBRARY NOTES.

The Library Committee desires to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

### MISCELLANEOUS.

Scientific Publishing Co., Manchester, Eng.—

Principles and Practice of Iron Founding. Rhead. Cloth.

Engineering News Publishing Co., New York—

The Slide Rule. Cajori. Cloth.

Methods Used in Preliminary Work on Catskill Reservoir. Langthorn. Pam.

H. M. Byllesby, M. W. S. E., Chicago—

Mechanics of Hoisting Machinery. Weisbach and Hermann. Cloth.

Safe Building Construction. Bergh. Cloth.

Roads, Their Construction and Maintenance. Greenwell and Elsdon. Cloth.

Gas Manufacture. Hornby. Cloth.

John F. Icke, M. W. S. E., Madison, Wis.—

Fourth Annual Report of Madison, Wis. Pam.

J. W. Pearl, Chicago—

Van Nostrand's Magazine. 4 Vols., 1883-4-5-6. Half leather.

N. W. Henley Publishing Co., New York—

Ornamental Concrete Without Molds. Houghton. Cloth.

Self Taught Mechanical Drawing and Elementary Machine Design. F. L. Sylvester. Cloth.

C. L. Gould, M. W. S. E., Chicago—

Barlow's Tables. Cloth.

Strength of Materials. Anderson. Cloth.

Practical Electric Railway Handbook. Herrick. Leather.

Elementary Geometry and Trigonometry. Bradbury.

Electric Street Railways. Houston and Kennelly. Cloth.

Engineering Drawing. Maxton. Cloth.

Elements of Machine Design. Urion. Parts 1 and 2.

Engineering Specifications and Contracts. Haupt. Cloth.

Mechanics of Hoisting Machinery. Weisbach and Hermann. Cloth.

Annual Report Indiana Geological Survey. 1898. Cloth.

Economic Theory of Railway Location. Wellington.

Lettering for Draftsmen, Engineers and Students. Reinhardt. Bds.

Strains in Framed Structures. DuBois. Cloth.

Estate of James McArthur, Chicago—

Civil and Military Engineers of America. Stuart. Cloth.

Mechanics of Machinery and Engineering. Weisbach. Parts 1 and 2. Cloth.

Lead Pipe Reports and Opinions. Cloth.

- Illinois State Commissioners of Charities—  
20th Biennial Report. 1908-10. Cloth.
- Trustees of Sanitary District of Chicago—  
Proceedings. 1909. Cloth.
- Thomas M. Gardner, M. W. S. E., Corvallis, Ore.—  
The Student Engineer. Vol 3, Nos. 1-5 incl. Pams.
- Col. Wm. H. Bixby, M. W. S. E., St. Louis—  
Reports and Maps on Survey of Mississippi River from St.  
Louis to its Mouth. Book and chart.
- Slason Thompson, Chicago—  
Railway Statistics of the U. S. 1909. Pam.
- C. L. Strobel, M. W. S. E., Chicago—  
Various Reports of the National Monetary Commission.
- Chicago Commission on City Expenditures—  
Preliminary Report on the Business Agent's Office of  
Chicago. Pam.
- The Purchase of Castings by the City of Chicago. 1907-9.

## MEMBERSHIP.

### Additions to Membership:

Akerlind, G. A., Chicago.....	Active
Alden, Emmons J., Chicago.....	Associate
Anderson, C. A., Chicago.....	Active
Armstrong, A. S., Chicago.....	Junior
Bartholomew, Irvin A., Nyssa, Ore.....	Associate
Bartholomew, J. B., Chicago.....	Active
Beck, Ralph O., Sioux City, Iowa.....	Junior
Blakely, A. J., Nyssa, Ore.....	Associate
Chadwick, Frank D., Spring Valley, Ill.....	Active
Courtney, H. H., Chicago.....	Active
Crawford, Thomas, Clinton, Iowa.....	Active
Fowler, Frank T., Chicago.....	Associate
Garner, H. L., Madison, Wis.....	Junior
Gayton, L. D., Milwaukee, Wis.....	Associate
Gilmore, Willard, Chicago.....	Junior
Hebblewhite, G. W., Chicago.....	Junior
Henderson, C. E., Urbana, Ill., transfer from Junior to.....	Active
Horn, George W., Chicago.....	Active
Jones, E. L., Chicago, transfer from Junior to.....	Active
Lara, Edward M., Chicago.....	Junior
Myers, Lewis E., Chicago.....	Active
Richards, T. E. Jr., E. St. Louis, Ill.....	Junior
Roberts, Paul S., Nyssa, Ore.....	Associate
Robinson, A. F., Chicago.....	Active
Ronneberg, Nathal, Chicago.....	Active
Runge, R. W., Milwaukee, Wis.....	Active
Simmons, I. L., Chicago.....	Active
Slocum, R. H., Fargo, N. D.....	Active
Smith, K. G., Milwaukee, Wis.....	Active
Smith, Robert J., Chicago.....	Junior
Warner, W. H., Chicago.....	Junior
Wright, T. J., Canebrake, W. Va.....	Junior

Since the publication of the Year Book for 1910, notice has been received of the death of the following members:

Nov. 28, 1909..	George H. Cooke, Terre Haute, Ind.....	Active
April 30, 1910..	S. W. McMunn, Chicago.....	Associate
May 8.....	Charles F. Foster, Chicago.....	Active
May 20.....	Richard Price Morgan, Dwight, Ill.....	Active
May 22.....	Samuel M. Rowe, Chicago.....	Active
May 26.....	James C. Long, Wynnet, Ill.....	Active
May 29.....	Hugo Arnold, Wilmette, Ill.....	Active

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## HYDRAULIC MINING OF AURIFEROUS GRAVELS.

JAMES W. PHILLIPS, M. W. S. E.

*Presented March 3, 1910.*

### INTRODUCTORY.

When valuable minerals have been removed by natural processes from rock in place and carried to beds of sand, earth, gravel, and boulders, and disseminated through such beds, the deposits are known as placers. According to the United States Revised Statutes, any deposits of minerals not found in place in veins of rock are placers. The process of obtaining placer-ores is known as gravel-mining or washing, the term hydraulic-mining being used when water under pressure is employed as an agent in the process of displacing the material.

In California, hydraulic-mining has been extensively developed, and these operations continued until they were stopped by legal enactments, except in the northern part of the state. The greatest body of auriferous gravel in the world lies in the central part of the state, and could be worked by the hydraulic process if the laws permitted. To attempt a description of hydraulic-mining in California, without reference to the great mines situated upon the tributaries of the Sacramento River—all of which have been permanently enjoined from operating—would be by comparison like a review of Roman history without a Cæsar or a Brutus.

The abandonment of hydraulic-mining in California is believed to be due to the passage of what is known as the Caminetti Act of 1893, and that this act was passed in the interest of the agriculturists, because of the great amount of debris carried down the rivers, which endangered not only their navigability, but flooded the lands adjacent to the streams, and deposited vast quantities of silt thereon. Mr. A. Caminetti was intimately associated with the mining interests of the state, and while representing California in Congress, he devoted himself energetically towards obtaining an equitable solution of the debris question. As a matter of fact, the fight between the miners on the one hand and the settlers and farmers on the other, in the alluvial valleys below the mines, had practically stopped hydraulic-mining before the passage of the Caminetti Act. This Act was passed, really to revive the industry, by permitting the working of hydraulic mines under proper regulations. The miners sympathized with the

farmers but believed they had a perfect right to extract gold from their claims by any method. The farmers had no desire to ruin the miners but believed the miners had no right to mine by methods that would ruin the farms. The fight was waged for years and the farmers won. The legal questions involved are discussed in cases to be found in 18 Fed. Rep., 753; 53 Fed. Rep., 625; 66 Cal., 138, all of which cases the miners lost. In 1881, the question was being discussed in all the papers and a fair presentation of the matter by Prof. Henry G. Hanks, State Mineralogist, may be found in the *Mining and Scientific Press*, San Francisco, of Dec. 10, 1881.

The Caminetti Act was passed for the purpose of reopening the hydraulic mines under the supervision of the Federal government, as having jurisdiction over navigable streams. It was approved March 1, 1893, and contains twenty-five sections.

In Section 1, a commission is created to consist of three officers of the Corps of Engineers, United States Army, to be known as the California Debris Commission.

In Sections 2 and 3 are fixed the organization, jurisdiction and compensation of the members of the commission; and in these sections we find such hydraulic-mining as was injuring territory drained by the Sacramento and San Joaquin rivers expressly prohibited.

Section 4 defines the duties of the board to be the restoring of said rivers and their tributaries to a condition as nearly as possible to that existing in 1861, and permitting hydraulic-mining to be carried on provided it can be done without injury to the navigability of said rivers or the land adjacent thereto.

Sections 5, 6 and 7 deal with the necessary examinations, surveys, and reports to carry out the provisions of Section 4.

Section 8 defines hydraulic-mining in the following words: "That for the purpose of this Act, 'hydraulic-mining' and 'mining by the hydraulic process' are hereby declared to have the meaning and application given to said terms in said state;" and the remainder of the Act contains all the details under which hydraulic-mining may be prosecuted. The California Supreme Court, in the case of Sutter County vs. William Nichols, owner of the Polar Star hydraulic mine, decided in effect that a license to mine by the hydraulic process, issued by the California Debris Commission, is no protection to the hydraulic miner, if anyone can prove to the satisfaction of a local court that damage is being done by the debris from the mine.

The total bullion-output of all the hydraulic mines situated upon the tributaries of the Sacramento river, operating under the supervision of the California Debris Commission, during the year 1906 was \$348,516; whereas the annual output credited for this district twenty-five to thirty years earlier was as much as \$10,000,000.

## THE NORTHERN CALIFORNIA HYDRAULIC MINES.

## Their Discovery, Location, and Methods of Working Them.

It is pretty generally conceded that Major Pearson B. Redding was the discoverer of gold in northern California, in July, 1848, during which year he crossed the mountain range between the Sacramento and Trinity rivers and prospected the bars along the latter stream, finding them rich in placer gold.

Since Major Redding's discovery, not less than 120 million dollars in gold have been taken out of the Trinity County mines alone. The Siskiyou county mines were discovered two years later, or in the spring of 1850. Within the confines of these two northern counties lie the principal auriferous-gravel deposits of California, capable of being worked by the hydraulic process at the present time without restriction, and I shall confine myself to a brief description of the gravel deposits of Trinity County and the methods employed in their working.

In Trinity County there are two separate and distinct kinds of gravel deposits,—the ancient river-channels and the bench deposits along the banks of the present streams. One of these ancient channels extends southwesterly through the northern end of the county, from a point a few miles north of Trinity Center, to a point near Junction City, a distance of about thirty miles. The bedrock of this channel is several hundred feet higher than the present Trinity river, and the surface along its line is over 1,000 feet in places, which gives a depth of gravel of over 500 ft. across the high ridges where the erosion has not been so great as at other points.

Gold is disseminated throughout this entire mass of gravel, though, like all other deposits of this character, there are some richer places where the gold has concentrated in a manner similar



Fig. 1. Typical Cross-section of Old River Channel.

to the rich leads of the present-day streams. It is the province of the prospector to seek out these enriched sections of any channel, and that of the engineer to devise methods for economically recovering the gold contained therein. For the purpose of illustrating the difficulties confronting the prospector in his

endeavors to find the pay-lead in a channel of this description, a typical cross-section of a channel is shown in Fig. 1.

The prospector with his limited means, and his tools consisting of a pick, shovel, and pan, cannot, as a rule, attack a deposit of this character from the top by sinking shafts, for in most places the channel is covered to a depth of many feet by disintegrated material from the adjacent mountains. After having familiarized himself with the character of the rocks forming the gravel contained in the channel, by an inspection of the workings at different points, a search of the gulches and ravines putting into the mountain-range towards the line of the channel will determine whether they have cut through the rim rock, by the similarity of the gravel in their beds. Having determined which streams have cut through the rim, the prospector proceeds to trace the gravel to the rim-rock, which will probably be an easy task if the stream is a large one where the erosion has been great, but a most difficult one in the dry ravines where the bed-rock is not exposed and where he must carry the dirt from his tracing-holes, several miles, perhaps, before getting sufficient water to pan it. If he be inexperienced he may follow a false trace, which, when he has carried it to its source, he may find has come from a seam in the country rock instead of from the channel sought. An old prospector will never be deceived by seam-gold, as the difference between it and placer-gold is readily determined.

The prospector, having made a discovery, is entitled to a location of 20 acres of land in his claim, and where two prospectors are associated, they may locate 40 acres in a joint claim; likewise, eight or more persons may associate together and locate a joint claim of 160 acres, but this is the limit in size of any claim, no matter how many persons there may be exceeding eight. In making a location the locator, individual, or association shall post a notice upon a tree, a post, or monument at the place of discovery, describing the name of the claim, the name or names of the locator, or locators, date of location, area of land located, and such description of the claim by reference to natural objects or permanent monuments as will identify the claim. When it is located with reference to, and conforms to the United States surveys, no further survey or marking of the boundaries of the claim are necessary.

The claim shall be recorded within thirty days of the date of location, in the office of the county recorder, for which a fee of \$1.00 is required. Only citizens of the United States, or those who have declared their intention to become such, are entitled to locate mineral lands. Where a location is made hereafter upon surveyed government lands, it shall conform to legal subdivisions of the sections wherein it is situated, as the General Land Office has refused to patent claims upon surveyed lands which do not

conform to the United States system of public land surveys and the rectangular subdivisions of such surveys; although in former years many patents were issued which did not so conform.

The prospector, before making his location, should carefully ascertain that he is upon the public domain and not upon land patented by the railroad company, which has acquired title to vast tracts of land in northern California, although Congress at the time of making grants of lands to railroad companies reserved all mineral lands to the United States.

#### WATER RIGHTS.

The Revised Statutes of the United States, in Section 2339, provides that, "Whenever, by priority of possession, rights to the use of water for mining, agricultural, manufacturing, or other purposes, have vested and accrued, and the same are recognized and acknowledged by the local customs, laws, and decisions of courts, the possessors and owners of such vested rights shall be maintained and protected in the same; and right of way for the construction of ditches and canals for the purpose herein specified is acknowledged and confirmed; but whenever any person, in the construction of any ditch or canal, injures or damages the possession of any settler on the public domain, the party committing such injury or damage shall be liable to the party injured for such injury or damage;" and, Section 2340 provides further that all patents granted, or pre-emption or homesteads allowed, shall be subject to any vested and accrued water rights, or rights to ditches and reservoirs used in connection with such water rights, as may have been acquired under, or recognized by, the preceding section."

The California law relating to water rights requires the person making the appropriation to post a notice at the point of the intended diversion, stating thereon:

1st. That he claims the water there flowing to the extent of (here insert number of inches claimed), measured under a 4-in. head.

2d. The purpose for which it is claimed, and the place of intended use.

3d. The means by which he intends to divert it, the size of the flume, ditch, pipe, or aqueduct in which he intends to convey it.

A copy of the notice must be recorded in the office of the County Recorder in the county in which the location is made, within 10 days of the date of the notice of location. Within 60 days of the date of location, the claimant must commence the construction of his flume, ditch, pipe, or aqueduct through which he intends to conduct the water, and must prosecute the work diligently and uninterruptedly to completion. The appropriation must be for some useful purpose, and the locator, or his successor

in interest, loses all rights to it when he ceases to use it for such purpose. After having acquired a right to the water of a stream, the locator, or the person entitled to its use, may change the place of diversion, provided others are not injured by so doing; and may also extend the ditch or other conveyance beyond the place of original use. The water of one stream may be turned into the channel of another and mingled with its waters, and then reclaimed; but in reclaiming it the water already appropriated by another must not be diminished. As between appropriators, the one first in time is the first in right.

In appropriating water measured under a 4-in. head, the inch must not be confounded with the legal miner's inch, which, according to California law, is equivalent to a flow of 1.5 cu. ft. per min.; whereas the inch measured under a 4-in. head is equal to a flow of 1.2 cu. ft. per minute.

The ditches constructed before the advent of hydraulic-mining were generally of small cross-sectional area and depended chiefly for their carrying capacity upon the great amount of grade they possessed. Some of these old ditches have been found by the writer to have a grade of twenty or more feet to the mile, and, when enlarging them to meet the conditions necessary

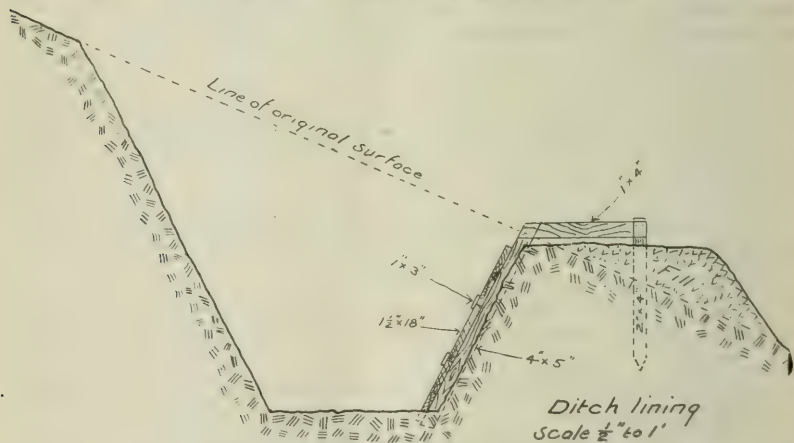


Fig. 2. Ditch on Hillside, with Lining.

for successful hydraulic-mining, viz., the carrying of from 2,000 to 3,000 miner's inches of water, the general practice has been to maintain the original grade and make a wide shallow ditch. Where the ditch is constructed through rock or cemented gravel, the maintaining of the original grade is recommended, but where the ditch is excavated through soil less compact, the practice has proven very bad, especially if the ditch is upon a steep side-hill where the alinement is a succession of curves. To protect these ditches from destruction, because of the swift current, lining the

outer, and in some cases also the inner banks with lumber or lagging has been resorted to; as shown in Fig. 2.

The first miners were gravel-miners, and the gravel mine is today called the "poor man's mine" because of the small equipment of tools needed. They put in ditches to carry the required water, and few, if any, of the earlier miners knew how to figure the flow of water and they put in their ditches by cut and try methods, but finally the judgment of an old experienced miner was wonderful on the subject of grades and quantity of water. A crude method of measuring water flowing through orifices under a head was developed, and the amount of water was the area in square inches of the orifice, regardless of its shape. The gravel-miner wanted to get water to the place where it was needed, and the possibility of washing the ground away was the only thing that prevented him from running his ditches in a straight line if possible, instead of following a grade. In many instances tunnels were cut and straight flumes put across valleys.

Following the first miners, and practically at the commencement of the hydraulic-mining era, there followed a generation of men, many of them surveyors and engineers, who used the following adaptation of the Eytelwein formula for open ditches:

$$v = \sqrt{(9000 \text{ rs} + 0.012)} - 0.11$$

or the following adaptation of the Poncelet formula

$$v = \sqrt{\left(\frac{9000 \text{ as}}{p}\right)} - 0.11$$

and for pipes the following adaptations of the Hawksley and Poncelet formulas:

$$v = 48 \sqrt{\frac{dh}{1 + 54d}}$$

in which  $v$  = mean velocity in feet per second.

$a$  = area of cross-section of water, in feet.

$p$  = wetted perimeter in feet.

$r$  = hydraulic mean radius in feet =  $a \div p$ .

$s$  = sine of slope =  $h \div l$ .

$h$  = fall in feet in any length,  $l$ .

$l$  = total length in feet on the slope.

$d$  = diameter of pipe in feet.

The foregoing formulas were printed in many handbooks given away by firms dealing in tools and machinery used by miners, and also in miners' pocket-books. They seldom appeared, however, in the forms here given, but were painfully

expressed in words like rules in arithmetic, with worked-out examples. They were used by a great many men who would have been scared by the sight of a formula. A tremendous amount of practical data has been stored up in the heads and notebooks of the older miners, but the engineer of experience in this line of work is better equipped than the practical man without scientific education.

As the mines grew larger, and the operations were conducted on a mammoth scale, the engineer was employed to run the ditch-lines and do all the work that called for education and skill in the handling of water. When the larger mines were finally shut down by the court, a large number of engineers had to seek other employment and many of them engaged in irrigation, but found it hard to come down from grades of ten ft. to the mile to that many inches sometimes. The classic experiments of Hamilton Smith on the flow of water in pipes were made for hydraulic miners, and the engineers employed from early in the 70's to the time the work was stopped were men of whom the state might well be proud and were a credit to their great profession. With the engineers employed by the larger companies, as with the engineers employed today, the favored formula has been the Chezy, viz.

$$v = C \sqrt{rs}$$

with the factor, C, computed by the Kutter formula, or the following modification of it, which is close enough for practically all use,

$$C = \frac{42 + \frac{2}{n}}{1 + \frac{42n}{\sqrt{r}}}$$

using the following values of n:

Planed boards	n = 0.010
Common boards	n = 0.012
Rubble	n = 0.017
Earth	n = 0.025

In surveying for a line, flumes and abrupt turns should be avoided whenever possible. It is always well to hit a hill hard in going around a point so there will be a good outer embankment. There should be a good roadway along all ditches, and on the lower side all obstructions, bushes, etc., should be removed in order that the lower bank, made by fill, will be solid. A number of hints might be given, but they are all summed up

by saying that the ditch should be in as firm ground as possible and constructed so it will not destroy itself.

Many of the older generation of miners have damaged the appearance of much of the country because of the steep grades on their ditches, and many abandoned-ditches have become ravines. The modern engineer and ditch-builder pays some attention to the character of the material through which the ditch runs. Careful attention to the following table of safe velocities, given by Sir John Neville in his *Hydraulic Tables*, is recommended for mean velocities.

0.42	feet	per	second	in	soft	alluvial	deposits.
0.67	"	"	"	"	"	clayey	soils.
1.00	"	"	"	"	"	sandy	and silty beds.
2.00	"	"	"	"	"	gravelly	earth.
3.00	"	"	"	"	"	strong	gravelly shingle.
4.00	"	"	"	"	"	shingly	soil.
5.00	"	"	"	"	"	shingly	and rocky.
6.67	"	"	"	"	"	and over,	in rocky formations.

A limit of about 15 ft. per sec. is set for first class masonry and wood, the bottom velocity being about two-thirds to three-quarters the mean velocity. The Dubuat formula for bottom velocity is as follows:

$$v_b = v - 11\sqrt{rs}$$

in which  $v_b$  = bottom velocity in feet per second.

$v$  = mean velocity in feet per second.

$r$  = mean hydraulic radius.

$s$  = sine of the slope.

In the reconstruction of these old ditches to meet the requirements of hydraulic mining the writer has always maintained that careful observance of the character of the material through which the ditch runs, and a careful stepping down of the grade at intervals of from one-eighth to one-fourth of a mile, would reduce the initial cost of construction as well as of maintenance. Throughout this section a grade of 6 to 12 ft. to the mile is as much as should be used.

The pioneer miners were a resourceful body of men and many difficult problems were solved by them in the construction of their tunnels, ditches, and other engineering works of magnitude. Miles of ditch-grades were run with only a buckskin thong with a rock tied to it for a plummet, attached to the apex of an A-frame made of three small spruce poles. The writer remembers, when, as a lad of eight years of age, he drove grade-pegs upon a ditch-survey run by his father, assisted by his (the writer's) brother, through five miles of the roughest country in northern California, with one of these "instruments of pre-

cision," and how in veneration he stood upon the brink of a deep canyon, the precipitous sides of which precluded a measurement with chain or tape, and witnessed his chief of party triangulate the distance across with accuracy and dispatch, and establish the grade with this simple contrivance with as much ease as the present-day engineer would accomplish it with his transit and stadia, or with the gradienter attachment.

The A-frame (Fig. 3), is made as follows:

Construct with any light material an A-frame with the legs extending 2 ft. below the cross-bar, and having a span of from 10 to 12 ft.; at the apex drive a nail and hang a plumb-bob from it with line sufficient to permit the plumb-bob to hang

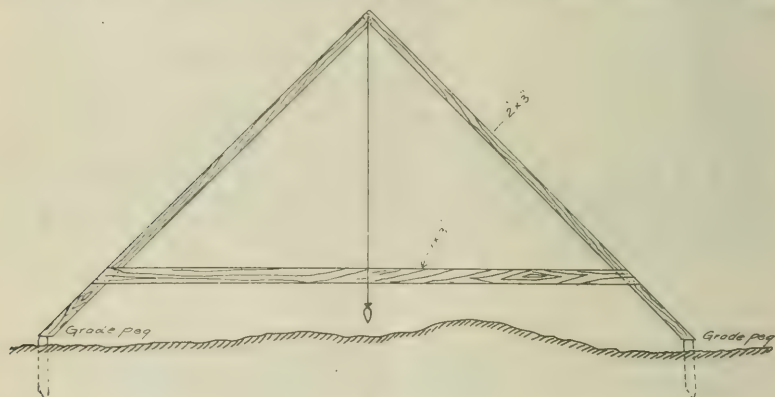


Fig. 3. The A Frame for Leveling.

below the cross-bar. This instrument is adjusted over two pegs as follows: Drive two pegs in the ground at a distance apart equal to the distance spanned by the legs of the frame; place the frame upon the pegs and note the position of the plumb-line at the cross-bar; reverse the frame and note the second position of the plumb-line between the two positions already noted, and drive the highest peg down until the plumb-line covers this midway mark on the cross-bar; the tops of the two pegs will then be at the same elevation.

Several methods are used for graduating the cross-bar to permit of grades being run, and one method is to rest the ends of both legs on the pegs after their tops have been brought to a level. Then one man at one end will raise the leg he holds to certain heights measured on a rule he holds on the peg, while another man will mark the position the string occupies on the cross-bar and will mark on it the grade. Thus falls of 1/16, 1/8, 1/4, etc., of an inch per station will be obtained, the stations being equal to the spread of the triangle, or base of the A-frame.

It is not claimed that the A-frame originated among the

pioneer miners of California, but it was used by them to lay out some of the longest ditches and tunnels constructed in the early days of mining in that state.

As a tribute to these men, the following from *A Treatise on Hydraulic and Water Supply Engineering*, by Col. John T. Fanning, is not amiss, it having been written in 1877:

*"Miners' Canals*—The sharp necessities of the gold-mining regions of California and Nevada have led to some of the most brilliant hydraulic achievements of the present generation. The miners intercept the torrents of the Sierras where occasion demands, and contour them in open canals, along rugged slopes, hang them in flumes along the steep rock faces, siphon them across deep canyons, and tunnel them through great ridges, in bold defiance of natural obstacles, though constant always to the laws of gravity and equilibrium.

"The force of water is an indispensable auxiliary in surface mining, and capital hesitates not at thirty, fifty, or a hundred miles distance, or almost impassible routes, when the torrents' power can be brought into requisition. A hundred ditches, as the miners term them, now skirt the mountains, where but a few years ago there was no evidence that the civilization or energy of man had ever been present.

The Big Canyon Ditch, near North Bloomfield, Nevada, for instance, is forty miles long and delivers 54,000,000 gallons of water per day. The sectional area of the stream is about 33 sq. ft. and the inclination 16 ft. to the mile. Its flumes are 6 ft. wide with grade of  $\frac{1}{2}$ -in. in 12 ft., or about 18 ft. to the mile. The contour line of the canal is from 200 to 270 ft. above the diggings, to which its waters are led down in wrought iron pipes. With a terrible power, fascinating to observe, its jets dash into the high banks of gravel, rapidly undercutting their bases, and razing them in huge slides that flow down the sluice-boxes with the stream.

"Thus in a single mine, 30,000 cu. yds. of gravel melt away in a single day, under the mighty hydraulic influence that has been gathered in the torrent and canaled along the eternal hills.

"The Eureka Ditch, in El Dorado County, California, is forty miles long, and there are many others of great length, whose magnitude and mechanical effect entitle them to consideration, as valuable hydraulic works, and monuments of hardy enterprise. The Eureka embankment is 70 ft. in height, flows 296 acres, and is located 6,560 ft. above the level of the sea."

## DEVELOPMENT OF A HYDRAULIC MINING PROPERTY.

## Preliminary Examination.

As the same conditions seldom exist at the different mining claims, no set of rules can be laid down for the guidance of the engineer. There are, however, three essential things that must exist in order to successfully develop a hydraulic mine, viz.:

1st. There must be an extensive deposit carrying gold in sufficient quantity.

2nd. There must be water in sufficient quantity that can be brought to an elevated position or placed under pressure sufficient to cut and wash the deposit.

3rd. There must be ample grade for the sluices and ample dumping area for the debris.

A superficial examination of the mine and its surroundings may be sufficient to determine approximately these essential features. Should this examination prove favorable, a careful and extensive investigation and survey of the entire property should be made and the channel or deposit carefully prospected.

## Prospecting the Deposit.

Where the depth of the deposit is not too great, shafts may be sunk to bedrock and the character and extent of the gravel determined by inspection. The shaft having been sunk to bedrock the deposit should be carefully prospected. Commence at the top and cut a section one foot wide and one foot back, down one side of the shaft, pan or rock the gravel for each five feet in depth, separately, and note their values.

In deep channels churn-drilling may be resorted to and a hole drilled to bedrock, disclosing the character and depth of the deposit and the value of the same. Special machines have been developed for doing this work, and in this section the favorite is the No. 3 Keystone Driller which has proved satisfactory in all character of gravel. In shallow ground the Empire Hand Prospecting Drill has proven to be practical. When operated by horsepower it has done good work upon holes 20 ft. and more in depth, where the gravel was comparatively free from large boulders. The ease with which it can be moved from place to place is in its favor when the ground is suitable.

Some years ago the writer had occasion to determine the values of a great many pan and rocker samples, and in order to facilitate the work computed the following table of values per cubic yard; it being based upon the assumption that there are 150 struck pans of 20 lb. each in a cubic yard of gravel in place.

Value per cubic yard of Auriferous Gravel based on the weight of the gold from 3 pans of gravel—the fineness of the gold varying from 0.780—worth \$16.00 per oz. to 0.907—worth \$18.75 per oz.—J. W. Phillips.

Weight of Gold in 3 Pans of Gravel	780 Fine \$16.00 oz.		786 Fine \$16.25 oz.		798 Fine \$16.50 oz.		810½ Fine \$16.75 oz.		822½ Fine \$17.00 oz.		834½ Fine \$17.25 oz.		847 Fine \$17.50 oz.		851½ Fine \$17.75 oz.		871 Fine \$18.00 oz.		883 Fine \$18.25 oz.		895 Fine \$18.50 oz.		907 Fine \$18.75 oz.	
	Val.	Cu. Yd.	Val.	Cu. Yd.	Val.	Cu. Yd.	Val.	Cu. Yd.	Val.	Cu. Yd.	Val.	Cu. Yd.	Val.	Cu. Yd.	Val.	Cu. Yd.	Val.	Cu. Yd.	Val.	Cu. Yd.	Val.	Cu. Yd.	Val.	Cu. Yd.
10 grains.....	\$16.64		\$16.92		\$17.18		\$17.44		\$17.70		\$17.97		\$18.23		\$18.49		\$18.75		\$19.01		\$19.27		\$19.53	
8 ".....	13.32		13.54		13.74		13.92		14.16		14.38		14.58		14.80		15.00		15.21		15.42		15.62	
6 ".....	9.98		10.16		10.30		10.46		10.62		10.78		10.93		11.10		11.25		11.41		11.56		11.72	
5 ".....	8.32		8.46		8.59		8.72		8.85		8.98		9.11		9.24		9.37		9.50		9.63		9.76	
4 ".....	6.66		6.77		6.87		6.97		7.08		7.19		7.29		7.40		7.50		7.60		7.71		7.81	
3 ".....	4.99		5.08		5.15		5.23		5.31		5.39		5.46		5.55		5.63		5.70		5.78		5.86	
2 ".....	3.33		3.38		3.43		3.49		3.54		3.59		3.64		3.70		3.75		3.80		3.85		3.90	
1 ".....	1.66		1.69		1.72		1.74		1.77		1.80		1.82		1.85		1.87		1.90		1.93		1.95	
0.9 ".....	1.50		1.52		1.54		1.57		1.59		1.62		1.64		1.66		1.69		1.71		1.73		1.76	
0.8 ".....	1.33		1.34		1.36		1.39		1.42		1.44		1.46		1.48		1.50		1.52		1.54		1.56	
0.7 ".....	1.16		1.18		1.20		1.22		1.24		1.26		1.28		1.29		1.31		1.33		1.35		1.36	
0.6 ".....	1.00		1.02		1.03		1.05		1.06		1.08		1.09		1.10		1.13		1.14		1.16		1.17	
0.5 ".....	0.83		0.84		0.86		0.87		0.89		0.90		0.91		0.92		0.93		0.95		0.96		0.98	
0.4 ".....	0.66		0.67		0.68		0.70		0.71		0.72		0.73		0.74		0.75		0.77		0.77		0.78	
0.3 ".....	0.50		0.51		0.51		0.52		0.53		0.54		0.55		0.55		0.56		0.57		0.58		0.59	
0.2 ".....	0.33		0.34		0.34		0.35		0.36		0.36		0.36		0.37		0.38		0.38		0.39		0.39	
0.1 ".....	0.17		0.17		0.17		0.17		0.18		0.18		0.18		0.18		0.19		0.19		0.19		0.20	

To explain the table, take three struck pans of gravel as it comes from the bank, scour it until thoroughly dissolved, then pan or rock the same carefully until all gravel and sand is removed; with a magnet remove all black sand or magnetic iron scales and dry the gold thoroughly, then weigh on accurate scales. If, for example, three pans of gravel contain 0.8 gr. of gold—the value of one cubic yard of gravel—gold being 0.847 fine would be \$1.46.

Use six to twelve pans when the values contained in the gravel are small, and take one-half or one-fourth the table values for the correct value per cubic yard of the gravel.

The placer-gold found in the gravel deposits of Trinity County range in values from 0.726 fine or \$15.00 per oz., to 0.931 fine, or a value of \$19.25 per oz.

The prospect holes should be close enough together throughout the entire tract to permit of a correct estimate being made of the values, and also to disclose the elevation and grade of the bedrocks, for upon a correct determination of the latter depends the subsequent economic handling of the gravel through the sluices.

The following notes are from a page in one of the field-books of the writer, and show his methods in noting prospect work:

Shaft No. 4—surface elevation 231.20 feet.

For the first 5 ft., red soil and small gravel, fine colors of gold.

From 5-ft. to 10-ft. Brown stained gravel, colors of gold, blacksand.

From 10 to 15 ft. Gray gravel, coarser, heavier gold.

“ 15 “ 20 “ Tight bonded gravel, coarser colors.

“ 20 “ 25 “ Larger boulders, water, tight gravel, heavier gold.

From 25 ft. to 30 ft. Boulders, tight gravel, little gold, bedrock.

Bedrock elevation 201.20 ft.

Bedrock is worn smooth. Evidently near main channel.

After the shaft was sunk to a depth of 5 ft., samples were taken down the east side of the same by cutting a vertical section 12 in. wide by 12 in. back, for the 5 ft. in depth. The gravel from this section was placed upon a platform and thoroughly mixed, then shovelled from the platform and every fifth shovel-full placed to one side for the sample. From this sample three pans of gravel gave 0.1 gr. of gold.

In like manner samples were taken as the shaft was sunk to bedrock and gave the following results:

From 5 to 10 ft.	three pans	gave	0.2 grains	gold.
" 10 "	15 "	" "	0.4 "	" "
" 15 "	20 "	" "	0.4 "	" "
" 20 "	25 "	" "	0.5 "	" "
" 25 "	30 "	" "	0.1 "	" "

The average of all the samples equalled 0.283 grs. The fineness of the gold from this gravel being 847/1000, or \$17.50 per oz. From the table we find 0.2 grs. of gold at 0.847 fine equals 36c. per cu. yd. and 0.083 gr. equals 15c., making a total average of 51 c. per cu. yd.

Where, owing to the loose condition of the gravel, timbering must be resorted to, the sample may be taken from one corner of the shaft after the rest of the shaft has been sunk low enough to permit of thoroughly draining the area from which the sample is taken. Samples should not be taken from the bottom of a shaft covered with water.

The results obtained by prospecting with a churn-drill are apt to be less reliable, so far as values are concerned, than those obtained by the shaft method. Unless the material drilled through is small compact gravel, a little gold is apt to work in from the gravel surrounding the casing, which raises the values per cubic yard above those obtained by actual working. In estimating the area of the drill-hole, the outside diameter of the casing is considered to be the diameter of the hole upon which the estimates are based.

In the third edition of the Keystone Driller Catalogue, No. 2, a method of estimating the values is given below, it being remembered that for many years the majority of the men engaged in hydraulic-mining were not book-buyers or students, and the manufacturers who made tools and supplies for them printed valuable catalogues, which are used as textbooks by many men today:

"Calculating the values is best shown by an example. The gold from, say, hole No. 14, weighed 2.22 gr.; this at 3.95c. per gr. equals 8.76c., the value of gold from hole No. 14. The cubic contents of the hole is next calculated. To do this, a factor called the pipe constant, or pipe factor, is employed. The inside diameter of casing is  $5 \frac{7}{8}$  in.; the outside diameter is  $6 \frac{1}{2}$  in. It is the practice of the district to use the outside diameter of the pipe as a basis for calculating its contents, the local engineers holding that it is the displacement of the pipe, and not the cubical contents, that should be used. Figuring the cubic contents per ft. of pipe, with a diameter of  $6 \frac{1}{2}$  in. would give 0.23 cu. ft. In practice it is found that 0.23 is much too small, giving values too high, which are not borne out by subsequent dredging.

"Some engineers use 0.25 as a factor. Radford's factor is 0.27—a factor obtained by Mr. W. H. Radford, a mining engineer of wide experience in this class of work, by the following method: Mr. Radford sunk a shaft 3 ft. in diam., using a drill hole as the center, to a depth of 34 ft. The gold obtained from the shaft corresponded almost exactly with the gold obtained from the drill hole when using 0.27 as a factor in the calculations. This factor is very important, as on it depends the value of the holes and consequently the final value of the ground. The difference in results obtained by using either the factor 0.25, or 0.27, is sufficient to change the value per cu. yd. from net to gross, i. e., a difference in some cases of 6c. to 8c. per cu. yd.

"Continuing the calculation: Hole No. 14 was  $29\frac{1}{2}$  ft. deep when drilling was stopped.  $29\frac{1}{2} \times 0.27$  gives 7.965 cu. ft. in hole drilled. Now we have the simple proportion, 7.965 cu. ft. of gravel drilled: 27 (the number of cu. ft. in a cu. yd.) :: 8.76 (the value of gold obtained) : x = the value per cu. yd., whence  $x = 29.69$ c. per cu. yd."

Another method given by the same company is known as the "Keystone Rule," which is as follows:

"Multiply the value of the gold (in cents) by 100 and divide by the number of feet drilled,—the result is the value of gold per cubic yard. This rule applies where the outside diameter of the casing is  $7\frac{1}{2}$  inches."

#### MAPS.

As soon as the property has been thoroughly prospected, a topographical map of the entire claim and its surroundings should be made to show all ditches, flumes, pipe-lines, sluiceways, tunnels, roads, and other improvements upon or appurtenant thereto. A working map should also be prepared, the scale of which should be as large as practicable.

Upon the maps the position of all prospect holes should be shown accurately, and the elevation of bedrock noted. Contour lines of the surface are shown at intervals of three feet where the surface-slope is not steep, and at nine-foot intervals upon steep ground. The writer cross-sections his maps into sections ten yards square, or one hundred square yards to one block, which furnishes a rapid means of estimating the number of cubic yards worked each month, by platting in the line of the bank as the work progresses. Contour lines are connected up to the bedrock elevations, in different colors, as the ground is worked.

At some of the mines there would be no advantage in having cross-section lines upon the map, as the surface of the banks breaks back for a distance of many feet beyond the working-face at the bottom, gradually working towards the workmen

at the bottom and continually changing its surface elevations. In such cases, whenever conditions permit, a rapid method for obtaining data on which to estimate progress, is to make a transit and stadia survey. By this method new contours may be quickly obtained, the transit being set up in any convenient place and two or more rodmen employed. The transit may be located by taking several sights to objects already correctly located on the map, and these lines of sight plotted upon tracing-paper or tracing cloth, all converging, of course, to the transit station. This transparent sheet can then be laid on the map and shifted into position so all the sights fit, when the transit station is pricked through on to the map, after which the sights will be plotted in the usual manner.

#### SLUICEWAY AND DUMP.

The elevation of the upper end of the sluiceway will be determined by the elevation of the bedrock at the most remote point from the dump. The ditch and flume and pipe-line convey the water to the giants (monitors they are called in Colorado), and the giants wash the gravel from the banks. The gravel and water run through a sluice with a floor, or pavement so constructed that the gravel will pass over it and the heavier gold will settle into the crevices.

Having the elevation of the most remote point, the elevation at the dump, and the distance, the grade is readily established. Mines are operated where the grade is as low as  $\frac{3}{16}$  in. to the foot, but from  $\frac{1}{2}$  in. to  $\frac{3}{4}$  in. to the foot should be used if it is possible to get that amount. Get as much grade as possible, and at the same time retain sufficient dumping area to permit of working the entire deposit, is the best rule that an experienced man can suggest. Where the material is sluiced through a bedrock cut, there must be about double the grade to maintain the same discharge that could be passed through a sluice paved with wooden blocks, rocks, or railroad iron. While these sluice grades are fixed by experience, the new man at the work may derive some benefit from the Chailly formula, which gives the velocity required to set in motion rounded stone or shingle,

$$v = 5.67\sqrt{ag}$$

or the Leslie formula,

$$v = 4\sqrt{a}$$

in which  $v$  = velocity in feet per second.

$a$  = average diameter in feet of the body to be moved.

$g$  = its specific gravity.

The Leslie formula ignores the specific gravity, so it is not general, but having been derived from experiments on material such as the hydraulic miners deal with, it is good enough for the man who works by formulas and prefers such methods to following the lead of old experienced men.

Wooden sluices are constructed upon the plan of a flume of the same general dimensions. The cross-section of a sluice is shown in Fig. 4 as used at one of the principal mines in this county. The widths of the sluices vary from 3 ft. to 8 ft., and the depth from 2 ft. to 4 ft. The quantity of water and gravel that can be put through any sluice depends of course

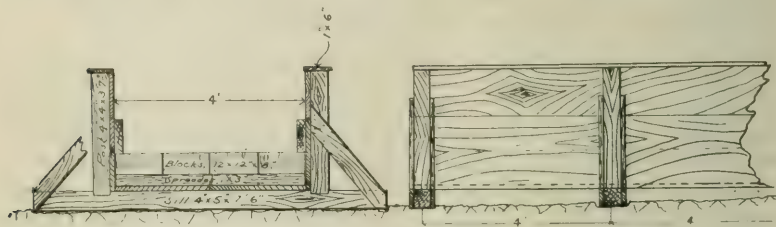


Fig. 4. Wooden Sluice.

upon the grade and the character of the gravel being worked. Tables have been prepared which purport to give the working value of a miner's inch of water when used for hydraulic-mining purposes, but such tables are of little value, as they are based upon certain conditions, all of which seldom, if ever, exist at the different hydraulic properties.

Experience shows that the quantity of gravel washed per 24-hour inch varies from one to ten cubic yards, the inch here being the legal California inch of 1.5 cu. ft. flow per minute.

At the La Grange mine, near Weaverville, the quantity of gravel run per miner's inch in a day of 24 hours has been estimated at approximately 7 cu. yd. Boulders weighing several tons are run through the sluices which are 6 ft. 3 in. in width, by 3 ft. 11 in. in depth, on a grade of 8 in. in 12 ft., and paved with steel railroad rails.

Where the mine is so situated that there is a limited dumping area, a separate hydraulic giant may be successfully used for stacking the tailings. Fig. 5 shows a mine operating under this condition. As soon as the dump has been filled with the debris piped into the sluices by the giant in operation, seen in the background of the illustration, the water will be turned into the string of pipe leading to the giant seen in the foreground, and the heavier material which has accumulated will be swept off to the right of the dump.

Where the deposit or channel to be worked is lower than the available dump, hydraulic elevators are used.

The elevator consists of a pipe rising at an angle from the bedrock to the sluices, which are placed at an elevation sufficient

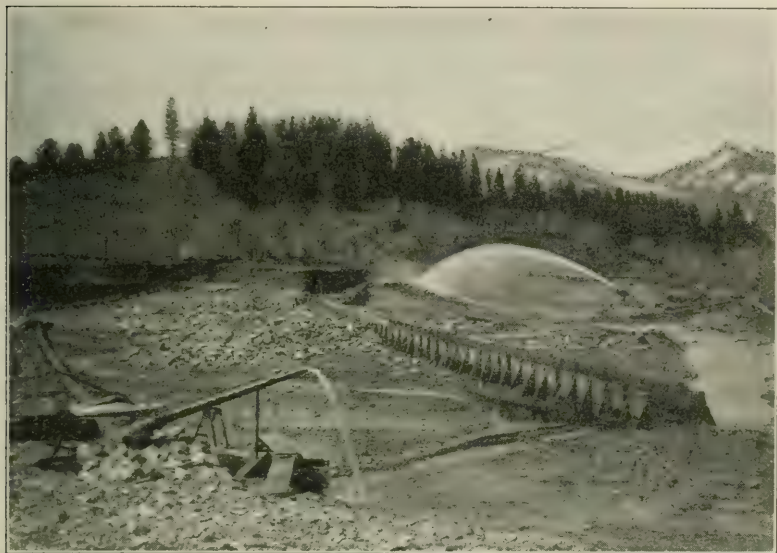


Fig. 5. Stacking the Tailings.

to allow the material forced up to run off by gravity to the dump.

At the lower end of the discharge pipe is a cast iron throat of smaller area than the main discharge pipe, through which a stream of water is forced by a high pressure. The material to be elevated is allowed to enter at the bottom, and the suction produced by the stream passing through the throat draws the material in and it is forced up through the discharge pipe to the sluices above. Hydraulic elevators require a high pressure, large quantities of water, and comparatively small boulders.

An elevating plant is being installed by the Joshua Hendy Iron Works, for the Trinity River Mining Co., near Lewiston, Calif., which has many novel features. The Trinity River Mining Company proposes to work the bed of the river, and in order to get rid of the water along the channel to be worked, have constructed a 1200 ft. tunnel which is capable of carrying the water in the stream for about five months of the year. This tunnel has a grade of 1% and the total fall from the stream at the entrance of the cut leading up to the tunnel, to the stream at the end of the cut at its outlet, is 26 ft. Turbine wheels are

placed at the outlet and a centrifugal pump is installed for forcing the water through the pipe leading to the giants and elevator. The result of the work that will be done with this plant, in the character of ground they have, is being awaited with much interest by the old line of hydraulic miners.

#### WATER AND DITCHES.

Water in sufficient quantity, under a pressure of from 200 to 400 ft. head, is the chief factor in the problem of successful hydraulic-mining.

The quantity of gold contained in the gravel may go as low as 3c per cu. yd., and the mine be worked to pay a dividend, provided the water and the dumping conditions are favorable, but I have known instances where, owing to a scarcity of water and lack of sufficient head, ground yielding 20c to the yard has failed to pay operating expenses.

The scarcity of water has been the greatest drawback in the development of the great auriferous gravel deposits of this county. Although the average annual rainfall is between 42 and 43 in., owing to the peculiar geological structure of the mountain ranges wherein the streams tributary to the Trinity River have their source, most of them are nearly dry by the middle of August, and the mining season is therefore limited to about eight months during the year. At the present rate of working by hydraulic process, it will be centuries before these great deposits will have been exhausted.

All of the water flowing in the streams tributary to the Trinity River for at least seven months in the year has already been located and is being used by the mining companies now operating. The only possible way that additional properties might be opened up in this field, a method that is entirely feasible, will be the conserving of the waste waters now being lost during the winter and spring freshets.

Ideal reservoir sites are to be found near the head waters of most of the streams in Trinity County, and the building of dams to hold sufficient water for all purposes presents no great engineering difficulties.

During the summer months the Trinity River has a flow of not to exceed 10,000 miners' inches at the town of Lewiston, whereas, with a watershed of approximately 800 sq. miles north of the town, the flow could be maintained at 99,000 in. throughout the year by a proper conserving of its waters.

Usually the most expensive portion of the hydraulic-mining plant is the construction of the ditch, flume, or pipe line, which conveys the water to the place of intended use. That mistakes have been made in the construction of ditches which were built in the early days of hydraulic-mining in Trinity County, is conclusively proven by the mute evidence presented by the

abandonment of some of the finest mining ground and best water-rights to be found in that section. One ditch in particular was built, which required the expenditure of at least \$150,000 for its 35 miles of length, and the water was never put through its entire length, and never will be, as the ground through which the ditch was made was entirely unsuited for ditching purposes.

Knowledge of ditch-building has been acquired principally through the deplorable mistakes of those who preceded us in this line of work, and today some of the finest water systems to be found are used in connection with hydraulic-mining plants. Practical experience is good in any line of work, but it is especially needed in the selection of grades for ditches through different characters of soil and rock. Where ditches are constructed through solid rock, close inspection is required that the contractors do not use powder to excess, for a ditch with the rock badly shattered is costly in maintenance and a very poor conveyor of water.

In regions where snow slides are apt to occur, the line must be covered, or a tunnel run beneath the surface, permitting the slides to pass over without doing damage. Small ravines must be flumed over the ditch or the ditch carried over the ravine, to allow the freshet waters to pass over or under the ditch.

Waste-gates must be provided at intervals of a mile or so for conveniently turning the water out of the ditch in case of emergency. The head-gates should be well bulkheaded to prevent an overflow into the ditch during freshets in the stream.

Where flumes are used in connection with a ditch, to convey the water around bluffs or through ground unsuited for ditching, they should be of the same cross-sectional area as the ditch, as there will be no increase of velocity where the lower end connects with the ditch. Should the flume reach to the lower end of the ditch and empty into the pressure box or a reservoir, then it may be constructed with due allowance for the increase in velocity which will take place because of the free fall.

All logs, brush, and other rubbish should be removed from the side hill immediately below the grade pegs, but should be so placed as to form a barrier for the retention of the earth and rock removed from the ditch, which would otherwise slide into the canyons and be of no use towards strengthening the lower bank of the ditch. If this earth is held in place for a few years it becomes settled and forms a portion of the lower bank, and by the time the logs rot out, it is solid enough to remain in position.

On ditches of more than five miles in length, patrol stations must be provided. Where the snow-fall is excessive and the region inaccessible during the winter months, two men are stationed at each patrol station. A telephone line connects the patrol

stations with one another and with the general office at the mine. An electric bell, actuated by a float in a well, connected with the ditch or flume, gives warning to the patrolmen during the night of any rise or fall in the water flowing in the ditch, denoting trouble at some point on the line. By means of the telephone, this is quickly located between the stations where it has occurred.

Tunnels are used extensively to shorten the line, and inverted siphons, constructed of riveted sheet-steel pipe, increasing in thickness of steel as the pressure increases, are used for crossing rivers and other depressions along the line of ditch. One of the tunnels on the line of the La Grange Mining Company's flume line is approximately two miles in length, and the longest



Fig. 6. Union Hill Mining Co. 30-in. Pipe Line Crossing the Trinity River.

siphon line on the same water-system crosses a depression of 1,100 ft., vertical measurement, and the pipe at the lowest point is under a pressure of 477 lb. per sq. in.

The siphon line of the Union Hill Mining Company, crossing the Trinity river, is shown in Fig. 6. This line is 4,800 ft. in length, is constructed of a riveted sheet-steel pipe 30 ins. in diameter, of No. 14 gauge at the intake and outlet, increasing to 5/16-in. at the lowest point, where the pressure is 275 lb. per sq. in. This depression is 634 ft. vertical measurement, and the siphon line has a head of 50 ft., which was computed to be sufficient to carry the

water of their ditch 3,000 miner's inches, but owing to the placing of an angle in the line, the siphon will carry but 2,400 miner's inches, with a mean velocity of  $12\frac{1}{4}$  ft. per sec.

The engineer who designed this line considered that the weight of the siphon and its contents would be sufficient to hold the line in place at the deflection angle, which was 26 deg., and was located at one end of the bridge which carries the line across the river. This bridge is a steel Pratt truss, with a span of 265 ft. and a clear width of 12 ft. It was also built to accommodate the travel from the mine to Lewiston, and thence to Redding, the nearest railroad point, so the siphon line was placed to one side of the center line of the bridge close to one of the side trusses. That the deflecting of the current passing through the line caused a greater strain than was expected, is evidenced by the lateral movement of the pipe at this angle, carrying the batter-post of the truss against which it was placed, and the destruction of the entire line, together with the bridge, would have quickly resulted had the water been allowed to flow through for any length of time. Under the supervision of Mr. C. E. Good-year, superintendent of the mine, the line was brought back into position and securely yoked, allowance being made for expansion and contraction of the line but allowing no lateral movement.

Air valves should be provided in siphon pipe-lines as well as in the lines which connect with the giants, permitting air to enter the pipe in case the water is rapidly drawn off by the parting of the pipe or the blowing up of a giant. In early days it was no uncommon thing for a pipe of thin steel to be flattened suddenly when the water was drawn out quickly. A water-valve must be placed in a siphon line at the point of greatest depression in order that the water may be drawn off when necessary.

#### RESERVOIRS.

Reservoirs of large capacity are an adjunct to a well-equipped hydraulic mine. Where it is possible they should be located at an elevation above the mine to permit of ample head or pressure for piping. Where the ditch is at an elevation sufficient to permit the use of giants, a reservoir can be quickly and cheaply excavated, or a crib of logs and brush may be constructed and the earth and rock sluiced in to form the fill, by using the giants to dislodge the material. Iron-pipe conduits have the advantage of permanency over wooden ones for conveying the water through the dam-wall of the reservoir, and iron gates have a like advantage over wooden gates. A waste-way must be provided for running the water around the point where work is in progress, during times of temporary repair.

#### MAIN PIPE LINES AND GIANTS.

The ideal pipe line for operating the giants must meet the following requirements:

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1st. It should connect with the distributing reservoir where the water is allowed to accumulate when the giants are not in operation.

2nd. The line should be of sufficient size to furnish water sufficient for at least three giants, any one of which may be operated separately from the others, or so connected that they may all be operated at one time.

3rd. The pipe should be laid in a straight line without deflection angles and upon ground that is not to be worked.

The line is composed of sheet-steel pipe, single or double riveted, depending, of course, upon pressure, in standard joints of 17 ft. each, although sections of any length to facilitate transportation may be had. Where the pipe is of large diameter and must be transported upon pack animals, the sheets may be had cut, punched and formed, in nests of 100 lb., the riveting to be done when received at the destination. To preserve the metal from rust and lessen friction of water passing through the pipe, all riveted steel pipe should be dipped in a hot coal tar or asphaltum compound.

Where a pipe line is intended to furnish water for three giants working under 300 ft. head, with 7-in. nozzles, the main line at the point where the Y is situated must be of ample diameter to pass a flow of water equal to 4,500 miner's inches. As the velocity depends upon pressure, with every decrease in pressure there must be an increase in diameter, to maintain the same velocity throughout the line. Gates are placed in the branch lines leading to the giants to permit the working of each giant independently if necessary. At all vertical and horizontal angles the pipe must be well braced, and the giants must be securely placed to prevent a blow-out. Air valves, as previously mentioned, should be placed along the line, especially after each change of grade, and expansion joints should be placed on lines that are riveted up throughout their entire length. As a rule, pipe lines for hydraulic mining are connected by slip joints when the line is under a head of less than 500 ft.

Where the line connects with the main ditch line, there should be a pressure box provided, the use of which is to catch all sand and other particles brought down the ditch, thereby preventing its entrance into the pipe line. The pressure box should be constructed with two compartments, the first designed to catch all sand and rocks brought down by the ditch, and which are flushed out from time to time, and the second for the entrance of the pipe line. If the pressure box is placed in the ditch, all the water not required for the pipe may flow through and on to the reservoirs without special arrangements being made for it, as is the case where the pressure box is placed to one side of the ditch.

After the water from the ditch enters the sand box, it overflows the partition and enters the main part of the pressure box

through a screen so arranged that all floating material is thrown off by the overflow when the pipe is filled. The depth of a pressure box should be such that a constant head of four feet may be maintained over the pipe line intake, for the purpose of excluding air from the pipe. A gate must also be provided to shut off all water from the pipe line when necessary.

#### HYDRAULIC GIANTS.

The hydraulic giant, the device for controlling the action of the stream for cutting and washing the gravel in the mines, ranges in size from No. 0, having an intake of 5 in. diameter, and an outlet of  $2\frac{1}{2}$  in., with the nozzle removed, to the No. 9, having an intake of 18 in., and an outlet of 11 in., using a nozzle as large as 10 in., if desired. Nozzles of different sizes can be used on each giant and a deflecting nozzle is frequently attached for the easy handling of the machines. There are many different giants on the market, but they all use either a double or a universal joint, for the purpose of deflecting the stream vertically and horizontally in any desired direction.

Where it is possible, one of the giants in the claim should be under high pressure, for the purpose of undercutting the bank where the gravel is particularly hard, or where it would be dangerous to bring a machine under low pressure close enough to perform the work.

At the Union Hill mine there are four giants which may be operated simultaneously or separately. One giant is connected with the main ditch line by 3,400 ft. of 15-in. pipe and is operated under a pressure obtained from a head of 490 ft. This giant is so stationed that it can be used for undercutting most of the bank. The other three giants are operated from a main pipe line 1,700 ft. in length, of 30-in. pipe, which connects with the receiving reservoir. The three lines of 15-in. pipe connect with the main line near the claim by a double Y, immediately below which connection are the gates for closing and regulating the water to the different giants. These three lines are under 200 ft. head, and are used principally for driving the material into the bedrock cut leading to the sluices. These three giants in operation are shown in Fig. 7.

In opening up a new property it is frequently possible to pipe out the cut in which the sluices are placed, washing the material through the first sluice boxes, and adding new ones as the work of piping the cut down to grade progresses.

At the Union Hill mine it was necessary to construct a tunnel, 1,140 ft. in length, in order to get grade for working the mine successfully. The sluices are laid the full length of the tunnel on a grade of 4 in. to 12 ft. and dump into the Trinity river 36 ft. from the face of the tunnel, having a dump of 49 ft. This is ample, as there is a wide bar along the opposite side of the river at that point, which allows the river to be forced out of its regu-

lar channel without damaging anyone. Each year the dump is swept away by the freshet waters, thereby allowing a continuation of the process indefinitely.

When this tunnel was first completed, an incline raise 40 ft. in length, connected with the surface of the bedrock in the claim, was used to dump into, but as the work progressed and the bank became more remote from this point, it was necessary to cut the bedrock up to the bank, into which everything is sluiced. This cut is now about 800 ft. in length and will increase as the work



Fig. 7. Three Giants at Work, Union Hill Mines.

continues. The sluice through the tunnel is 5 ft. wide by 3 ft. deep, paved with wooden blocks 12 in. thick, having a 2-in. spreader between them, with the exception of the first four boxes, where the blocks are 4-in. wide with a spreader between them. A drain box is placed along one side of the sluice immediately under the walking plank, and permits draining the water out of the sluice when it is necessary to have it dry while replacing the block pavement. During the clean-up a head of water is run through the drain box, in which riffles are placed, the walking plank is temporarily raised and the gravel which has lodged in the spaces between the blocks, together with the gold it contains, is shoveled into the drain and sluiced through quickly. This allows a recovery of the gold and permits the replacing of the

blocks as the work is going on, thereby saving time, not only in washing the dirt but in replacing the blocks. This is shown in Fig. 8. With the light character of gravel found here, these blocks will wear about two seasons. At the end of the sluice, where it dumps into the river, an undercurrent is placed, and here is recovered  $1\frac{1}{2}\%$  of the gross values from the mine.

An undercurrent is practically a broad shallow sluice placed near the end and to one side of the main or intermediate sluices, and approximately three feet lower in grade. An auxiliary sluice of small sectional area leads from underneath the main sluice to

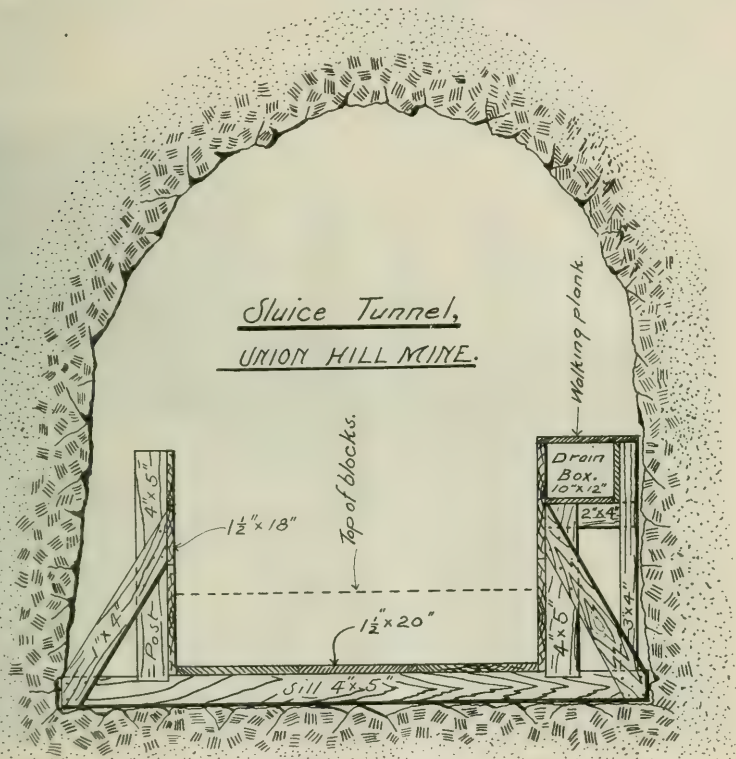


Fig. 8. Tunnel Containing Sluice.

the head of the undercurrent. The material passing through the sluices passes over grizzly bars placed transversely in the bottom of the same, the finer material passing through the grizzly into the auxiliary sluice and thence to the undercurrent over which it flows in a broad shallow stream, thereby permitting the finer particles of gold to settle in the riffles provided for the same. Undercurrents are from 12 to 20 ft. in width, and are at times

constructed with a partition leading through the center from the upper to the lower end, thereby permitting the material to flow on one side while the other side is being cleaned up or repaired. Their grade should be one inch or more to the foot and the riffles are usually placed transversely to the line of flow. Fig. 9.

In the recovery of gold from this mine the percentages run as follows:

Upon the bedrock and in the bedrock cut before it reaches the sluices.....	30 %
In the first four sluice boxes.....	30 %
In the next six sluices.....	20 %
In the rest of the sluices .....	18½%
In the undercurrent .....	1½%



Fig. 9. Under Current.

Mercury is generally used in the sluices and in the undercurrents for amalgamating the finer particles of gold, but it is bad practice to put it in the bedrock cut leading to the sluices, as it is exceedingly hard to recover from the cracks in the rock. When used, the amalgam is retorted before being shipped to the mint, and the gold should be melted and run into a brick, the value of which is determined by assay before shipment.

## SAW MILL.

Lumber being one of the largest items of expense connected with the fitting up of a hydraulic-mining plant, a sawmill should be erected as soon as possible and the timber growing upon the claim, which is frequently sufficient for all purposes, cut into lumber and blocks as the clearing of the land, preliminary to mining operations, progresses.

Where the mill is conveniently located, the lumber may be cut for about \$8.00 per M. ft. B. M. Lumber in this market costs, delivered at the mines, from \$35.00 to \$40.00 per M. ft. B. M., depending upon the distance hauled. The standard dimensions of flume and sluice lumber are as follows: For sluice bottoms and sides,  $1\frac{1}{4}$  in. to  $1\frac{1}{2}$  in. by 18 in. to 24 in. wide and of 12 ft. lengths. For posts and sills, 4 in. by 4 in., 4 in. by 5 in., and 4 in. by 6 in., depending upon the width and depth of the flume.

## DERRICKS AND ROCK CONVEYORS.

Where the ground is comparatively shallow and there is insufficient grade and dump to permit of all the boulders being sluiced to the dump, a derrick should be installed for handling



Fig. 10. Removing Boulders.

the larger boulders. Where the boulders are exceedingly large, the practice has been to "bull-doze" them with blasting gelatine, or dynamite, breaking them into pieces of sufficient size to allow handling with the derrick. Where rock is "bull dozed," an excess of powder is used and it is far more economical to employ small air hammers or drills for drilling the boulders, using a small air compressor, run by the same power that is used for operating the derrick. Where the bank is very high and it would be dangerous to operate a derrick, an overhead trolley system is used for removing the boulders. Fig. 10 is a sketch copied from the Third Biennial Report of the State Mineralogist of California, illustrating the removal of boulders.

## BEDROCK CLEANING.

After the gravel has been piped off and the bedrock is bare, it should be cleaned of all gold before being covered with the boulders, which are thrown back. Formerly the work was done by scraping and brushing with a stiff hand broom. An innovation in the method of performing this work was inaugurated by Superintendent Goodyear at the Union Hill mine last summer. It has long been known that a dipper full of water poured into a crevice will boil out the gold when it is impossible to recover it in any other way, so this principle was used by Mr. Goodyear to clean the bedrock stripped during the season's work.

A water-tank was placed on the bank above the bedrock and a 2-in. pipe was run from it to the point where the cleaning was going on. A piece of hose was attached to the end of this pipe, which permitted the operator to work over considerable area without adding more pipe. The water in the hose was under a pressure of 35 lb. to the square inch, which was sufficient to boil out the gold which had lodged in the cracks and crevices of the rock, and to sweep it along, together with the sand and light gravel, thereby permitting one man with this contrivance to perform with ease the work formerly requiring a dozen men.

## LIGHTING.

The work in the mines continues without cessation, except for temporary repairs, during the mining season, so it is necessary to illuminate the working pit and also the sluiceway during the night. Electric lights are used at some of the properties, while at others acetylene gas is found to give a strong light and can be conveniently moved from point to point, thereby concentrating the light along the bank where the work is being done.

Where there are no electric lights in the tunnels, candles are used when light is necessary. The cheapest and best candlestick to be found is a ball of clay, of the consistency of putty, which may be stuck to the side of the tunnel at any place, or in any position, allowing the light to fall upon the desired point. Miners' candlesticks cost from \$1.50 to \$2.50 and give no better satisfaction than the clay ball.

## WASHING GRAVEL.

After the claim has been opened, the giants should be set so as to best assist one another in handling the gravel. The quantity handled depends upon the character of the gravel—whether coarse, cemented, or a high percentage of large boulders—and also upon the skill of the operators. Where the material washed is composed of both coarse and fine gravel, care should be observed that there is sufficient fine stuff sluiced with the coarse to permit it to run through the sluices. It is almost impossible to sluice boulders alone, but if there is some fine

stuff with the boulders, no trouble is experienced if the water supply is sufficient.

The waste water should be brought into the mine through a pipe and giant, even though the pressure head is not more than 75 ft., for with this light pressure the stream can be thrown from place to place, assisting the main giant in washing the material which has been previously cut down. Fig. 11 shows a mine operating with a single giant and the waste water being run over the bank to assist in washing the gravel through the sluices.

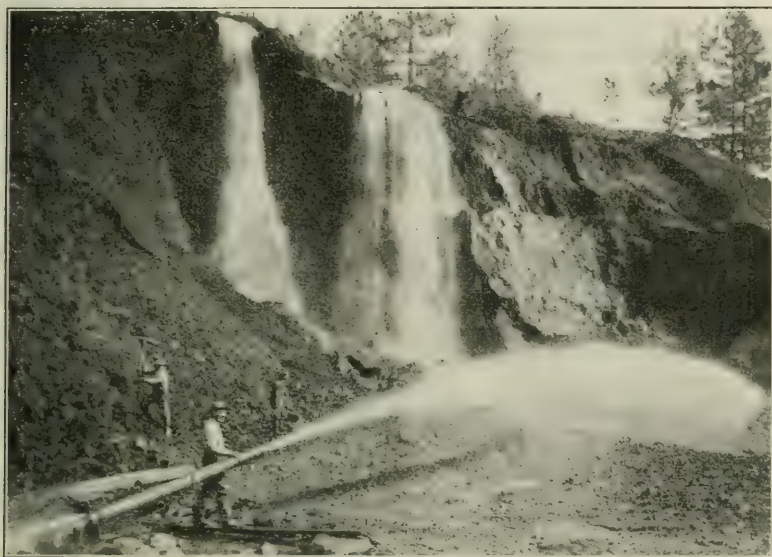


Fig. 11. One Giant at Work, and Waste Water Coming Over the Bank.

This stream could probably have been used with better effect by putting it through a giant as just described.

#### LABOR AND COST OF MATERIAL.

Wages are about as follows at the different mines:

Pipers receive 30c. an hour for a 12-hour shift, deducting 75c. per day for board. General workmen receive \$2.75 per 9-hour day and pay 75c. per day for board. Freight rates from Redding, the nearest railroad point, are from \$18.00 to \$25.00 per ton.

For comparison as to costs of other material, the item of cement, which costs approximately \$1.50 per bbl. in Chicago, cannot be had for less than 9.00 per bbl. in Lewiston. At other places in the county, where cement has been used, the cost has run as high as \$13.00.

The old saying that "It takes a mine to run a mine," is a true one.

The writer is indebted to Mr. C. E. Goodyear, Superintend-

ent of the Union Hill mine, for valuable data and photographs of the work being performed at that mine, also to Mr. Milan Senger, his able and courteous assistant, and Mr. G. W. Yount for photographs of mining scenes.

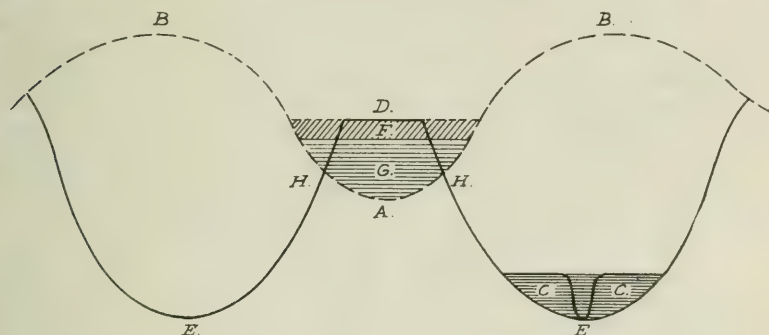
#### DISCUSSION.

*Mr. O. P. Chamberlain:* M. W. S. E. (Chairman). We have all been interested in hearing Mr. Phillips' paper, as presented by Mr. McCullough. For my part I realize better than I ever did before the immense amount of water that is required in this method of mining. I presume there are some present who are familiar with this work and we shall be glad to have anyone open the discussion or ask questions.

*Mr. W. B. Storey, Jr.,* M. W. S. E.: Preliminary to my remarks on the subject of hydraulic-mining, I wish to say that the commission, spoken of by the author, was organized in 1893, under the Caminetti Act, and I became the first inspecting engineer for the commission. In that capacity I saw the inauguration of the dump-restraining works and the attempted revival of hydraulic-mining under the Caminetti Act. In addition to that experience I had an opportunity to visit a very large part of the hydraulic area of California which was affected by the Caminetti Act and by the stoppage of hydraulic-mining by the courts, as has been described by the author. The particular field of mining which is now in operation is located in a part of California that is not in any way subject to the state control, because the streams which carry the debris away empty directly into the ocean and do not go through the San Joaquin or Sacramento valleys, which are the only ones covered by the Caminetti Act. It is the only district in California which is being successfully operated today by the hydraulic process.

The statement was made this evening that the methods used in the hydraulic process had resulted in moving materials and obtaining gold at a much less cost than formerly. As a matter of history, I will say that this method of handling material in order to get out the gold was a matter of evolution—and the evolution was extremely rapid—due to the needs which presented themselves after the discovery of gold in California. The original miner used a pan, as has been shown; this was followed by the rocker; and later the sluice, which turned a current of water into a confined area, was used, the miner shoveling his material into the sluice and the water carrying it 20, 40, 60—different lengths in feet; as the operations grew, the size of the flume and the way of getting material into it developed, and from that came the playing of a stream of water onto a bank. This bank at first was low. I have seen streams not as large as the stream which goes from a fire engine played against a bank possibly 5 to 6 feet high, and from this a flume led, not quite a foot wide—possibly fourteen inches—extending for a distance

of perhaps a quarter of a mile; the riffles in the bottom of this were also very crude—not nearly as elaborate as described in the paper, which is the result of the long development and the continued amount of energy that has been used in developing this method of mining. From this small beginning grew the immense streams of water, the great ditches and the piping methods, and economical handling of the material that has been so well illustrated in the paper. The work was done largely



*A = Old Channel*

*B = Old Mountain Top.*

*D = New Mountain Top.*

*C = Gravel Bench*

*F = Lava Cap*

*G = Gravel Deposit*

*E = New Channel*

*H = Rim*

Fig. 13. Typical Cross Section of Old Channel and Present Water Course.

washing free gold from the material in which it has been deposited. In one of the current magazines I saw a cut or diagram illustrating the formation of the so-called channels and gravel beds, and I will attempt to place this on the blackboard for the benefit of those who may have no knowledge whatever of the particular way in which this occurs. We will assume the cross-section of the country across several canyons, or ravines, and by men not engineers, so-called, at that time, but they were engineers in the very highest sense of the word. They evolved results from the means which were available. While possibly they had no formulae to apply and no knowledge obtained from books, still they achieved results—magnificent results—and we have learned a great deal from what they did.

Primarily the hydraulic process of mining is essentially that the original shape of the cross-section was as shown by the dotted line, the water flowing through *A*. In the erosion of the country the gold has been carried down from *BB* toward *A*

and deposited. In the course of years, centuries, perhaps thousands of years, the gold which occurred in the country rock, loosened by erosion, has been carried by this process of washing toward the center and has reached, as a rule, the lower part of the stream or channel through which it is carried toward the sea, and may have traveled down-stream 5, 10, 20, or 30 miles. After the collecting process, a convulsion of nature followed, in which a flow of lava has run over the top of the gravel. The depth of some of these beds of gravel is at least 400 feet. As the lava comes from some point higher up in the range it of course follows the lowest ground, just the same as water, and later solidifies over the top of the alluvial material underneath. In succeeding ages it is scoured at the edges and is cut deeper and deeper, until ultimately the cross-section takes the shape shown in the sketch. The erosion has continued until finally there is a gorge, or ravine, *EE*, on each side. These sometimes are 1,000 feet deep—possibly deeper—and on top of the mountain will be found the so-called old channel, *G*, with its lava-cap, *F*.

The reference in the paper to old channels is to such places as have been described. As the years go by, some of the gold and some of the material from the old channels are carried down into the new gorge and new deposits are formed. In a still later period these later deposits are cut into and portions of the gravel remain on the walls of the canyon, forming benches, *CC*, mentioned by the author, and in these gold is also found.

There are two methods of mining for this gold. One is to tunnel through the rim, *HH*, of the channel, and having found the bottom to follow it on the up-grade. It is difficult to follow it on the down-grade because there is generally too much water. As a consequence, the tunnels work upstream and one can follow on the grade of the country just as it existed in the original days, when it was actually the bed of a stream and the water was flowing in it. The richest ground will be found generally close to the center of the channel. Gold in quantity will be found on the bedrock, but scattered through much of the gravel will be a sprinkling of gold. In some places very little gold exists in the upper portion, and in other places it is scattered evenly through the deposits and is found for the entire depth, but may run only 2 or 3 cents per cubic yard. The drifting method, however, cannot recover such small values and is therefore confined to the lower or bedrock ground.

Following the method of tunneling came the method of washing and, operations grew larger and larger until the amount of capital invested in the mines was millions of dollars, and the work undertaken to carry on this amount of mining, to provide the water the "giants," and the men, cost many millions dollars.

The water was impounded miles away and was brought by long expensive ditches to the mine. The dump could only be

found on lower ground and long deep trenches, and in some cases tunnels are needed to reach the sides of the canyon where the debris can be turned loose. This debris is what finally led to the cessation of hydraulic-mining on the watersheds leading into the Sacramento and San Joaquin rivers, because in times of flood and freshets the material was carried from those dumps to the lower lands, and to the beds of the rivers, ruining land and injuring the navigability of the streams. In some cases the dump is provided by elevating all the debris to a level high enough to get the necessary fall.

There are three important factors in successful hydraulic mining: the deposit of material with the proper amount of gold in it, the proper supply of water, and the proper dumping-ground. I have known of schemes which had the first two factors, and the last seemed to the parties interested as being immaterial—they thought they would find some way to carry off the debris and get rid of it and still save the gold—but the schemes failed simply from lack of proper dumping-ground. There must be proper fall and proper ground on which to throw the washed material. One of the things that must be taken into consideration is the farmer on the land below. No matter how small the proposition, if the injurious material is being thrown on to the farmer's land—filling up the stream so that it floods out on the farm—even if it is only two or three miles below, he will stop the work. So the three things mentioned are absolutely essential in successful hydraulic mining.

*Mr. I. F. Stern, M. W. S. E.:* Mr. Storey has given two theories for the deposit of the gold at the point *A*. The tests indicate that an increasing percentage of gold should have been found in going down. Am I correct in my understanding?

*Mr. E. McCullough, M. W. S. E.:* The author showed the amount of gold he found as he went down into the prospect hole.

*Mr. Stern:* Then the amount of gold, in going down, should have gradually increased to the rock and should have shown greatest at the rock?

*Mr. Storey:* My illustration was not a concrete example of any kind, and it simply shows the general processes through which the country has been eroded and the gold deposited in the river-channels. I would point out, however, that the processes by which this material was deposited may have been varying in their nature. Possibly gravel may have deposited at one point for 5, 10, or 15 feet, extending over a long period of time; then possibly clay, or something of similar nature, was deposited; cement may have formed on it. Then gold will be found deposited on this higher level. The paper describes different classes of material—some of it dry, some with boulders, some cemented, and some with very high banks. I have seen many

different kinds and layers of material, and yet very little gold in some places and more in other places.

*Mr. McCullough:* The author found from 5 to 10 feet brown stained gravel, colors of gold and black sand. There three pans gave 0.2 gr. of gold. Then from 10 to 15 feet he found 0.4 gr. in three pans; from 15 to 20 feet was coarser gold; that also was 0.4 gr. From 20 to 25 feet he found large boulders with some water, tight gravel, and heavier gold, and found 0.5 gr. of gold. Then from 25 to 30 feet it was boulders, tight gravel and very little gold.

*Mr. Stern:* I understood Mr. Storey to say that the aim was to follow the old bed of the stream with the expectation of finding the largest amount of gold there.

*Mr. Storey:* In following the old bed of the stream, in many places much gold is found there, while in other places not enough gold has accumulated to warrant drifting. The miners burrow around for awhile and finally abandon the place, if they do not find enough gold in the channel to warrant going on with their operations. I have seen a gravel-bank uncovered, under which the old tunnel operations could be seen, with the timber standing, and so forth, showing that the bank had been burrowed out many years before the hydraulic operations were begun.

In this connection I might point out that the form shown in the sketch is the simplest one in which deposits of this kind can be found. There is one particular place in California in which it is as shown, and that is a typical cross-section through Table Mountain, in Stanislaus county, made famous by Bret Harte. Table Mountain, looking out from anywhere down in the canyon on the north, gives one a long, apparently level, sky-line, and in climbing up on top it is found to be possibly half a mile wide. At the edge it is just as deep down into the south gorge as it was in the north gorge, and that sky-line lava-cap can be seen and traced for over 30 miles. It has, however, the general gradual slope of the Sierra Nevada mountains, and it follows practically parallel to the grade of the old channel which is underneath.

*Mr. John G. Elliott:* I think that Mr. Stern wanted to know how Mr. Storey accounted for the fact that in the deepest part of the channel the gold may be less heavy than on the higher levels.

*Mr. Storey:* In the deepest part of the channel, the gold is not less heavy but it is simply all through the mass of gravel because there happens to be material located there at the time. If a stream of water large enough to start the entire mass moving could be obtained, the gold would go to the bottom, unquestionably, just as it does in the flume.

*Mr. Elliott:* What would be the result if the material were loose gravel?

*Mr. Storey:* If one starts in with simply a narrow gorge, the material will be washed down there for a long time before it begins to deposit at all, and the gold from above will deposit in the bottom. Later, and as the layers of gravel or materials which are not easily eroded are deposited, the gold will lodge on top of the various layers, so that it will be found all through the mass. In certain parts of California, as a school boy I have gone out into the red earth alongside the road and have gone to bedrock. We boys took old pans and things of that sort and could get a "color" of gold almost anywhere. The gold was not necessarily down in the gorges, it was just simply all over the country, and was in fine, small particles.

*Mr. Warder:* Is it not supposed, Mr. Storey, that all of the gold has come from original quartz-veins that have been broken down by the action of the elements and carried forward during the process of erosion?

*Mr. Storey:* It is assumed that the gold has come from quartz-veins which were originally protruding up through the old surface of the ground, and perhaps hundreds of miles away. They would be like veins sticking up through the rock, and were washed out as the country was eroded. Some of the samples of gold which are exhibited here this evening show its form as it comes out of the quartz before it has been rolled and carried far down the stream, but other samples show the rounded and hammered surface, the result of being transported further into the lower stream.

*Mr. Elliott:* The stream might be considered natures' sluice-box.

*Mr. Storey:* Yes; man, in making the sluice-box, has simply improve on nature a little.

*Mr. Elliott:* I am familiar with mining in some parts of California. There one finds the blue gravel on the bedrock, and above that there is from 10 to 30 feet of lava-ash; then above that will be found probably 40 or 50 feet of cemented yellow gravel. At this place it is 90 feet down to the bedrock, and within about 6 or 7 feet of the top (as I now recall it) is another layer of this lava-ash, as it is called in common terms. About  $2\frac{1}{2}$  miles below this property is what is known as Central Hill, where two channels join. On top of this hill there are quartz-boulders and oftentimes ashes, which I think tends to show that at one time the bed of the river was raised up by immense deposits of lava-ash about 510 feet above the present surface of the property I refer to, whereas at other places erosions cut gullies down to bedrock and carried the gold away and scattered it all over the country. The top gravel that is above the lava that lies next to the blue gravel can be panned anywhere, and it is worth from 5 cents to 15 cents per cubic yard.

*Mr. McCullough:* Gravel mining, as generally understood, is

simply getting the gold out of the gravel, washing it with water; it is called hydraulic-mining when water is applied under pressure. All around the neighborhood of Oroville the country is full of prospect-holes where men used to dig right down to the bedrock; holes were dug 5 to 10 feet in diameter, the stuff was hoisted to the top in buckets and was then washed on the surface. The Chinamen used to do a good deal of this work. Again men went over that same country with the hydraulic process and obtained a good deal more gold.

*Mr. Storey:* Possibly pertinent to this whole subject and worthy of mention is the fact that in California, in that region where the hydraulic-mining was stopped, people are now doing a great deal of placer-mining by dredging. They build an enormous machine that costs from \$50,000 to \$75,000, in a hole which they have dug in the gravel, fill the hole with water, then take up the gravel in front, wash it, and deposit it behind the machine. That overcomes the difficulty which has been mentioned of sending the debris down the river and enables them to get a good deal of gold. Of course the ground has to be considerably richer than the 3 to 5 cent gravel such as we have been discussing, in order to do that, but very large values have been recovered by that method in certain parts of California.

*Mr. Elliott:* How deep is the gravel in which those dredges are used? I understand that ordinarily they are about 30 feet thick, or less. Suppose there is 90 feet of gravel.

*Mr. Storey:* It is impossible to get down to the bottom with the dredges, and all that can be done is to take the gold that is found in the gravel as deep as it can be reached with the machine.

*Mr. Elliott:* What depth can be reached with one of those machines?

*Mr. McCullough:* I have operated three patent dredges and the greatest depth reached with any one of them was 18 feet, although I have seen claims made of working the machines to a depth of 30 and 40 feet. The miners do not seem to be able to work the dredges profitably to any greater depth than 18 to 20 feet.

*Mr. Elliott:* Do you think that the debris laws of California are an advantage or a disadvantage to the state?

*Mr. Storey:* I have not given that question any thought whatever.

*Mr. Elliott:* I mean as to the value of the gold that can be taken out as compared with the value of the land as farm land. One rather selfish way of looking at the matter is whether one has obtained the best result when he has obtained the most money, or whether he has left the land and the country in such shape that future generations can survive. In the case of the

miner, he has taken out the gold and it is gone. As it is at the present time, the land is preserved and we do not know how many thousands of years it may be used and utilized. But the way of looking at the matter which really obtains is, what is right? It was difficult for the miner to see that it was right for the farmer to stop him, but there is no question at all but that the farmer had a right to protect his land from another above him, and that one man should not be allowed to dump his material on another man's land without compensation.

*Mr. Oscar E. Strehlow, M. W. S. E.:* Where dredges are used, the difficulties are much simpler, as I understand it; that is, the amount of water, the dump ground, the slope, and the sluices are dispensed with. I presume that is the reason they have been adopted.

*Mr. Storey:* The dredging process is much simpler but also more unsatisfactory. As much material cannot be handled, nor as cheaply, as with the other methods. One of the reasons that material can be handled so cheaply by the hydraulic method is the enormous quantities that are handled and the enormous amount of water used that costs but little per million gallons. This does not obtain in the matter of the dredges, so that higher values are necessary and the amount of material worked must be very much less.

*Mr. McCullough:* Some of these dredges are so fixed that the sluice is all on the dredge. It will run down backward and forward and discharge the waste material over the rear end of the dredge.

*Mr. Storey:* Yes, but the deeper dredge is somewhat better; the cost of operating is excessive, and if one happens to drop into a poor hole he loses money very rapidly.

*Mr. McCullough:* The question of dump referred to by Mr. Storey is an important one, and a great quantity of these stackers are used in places where the dumping is poor. They are ladder-like arrangements, up which the monitor forces the rock. I have seen them 40 ft. high and 50 ft. wide. Head can be saved that way, and an artificial dump can be obtained, but it is unsatisfactory. I have seen those stackers operated at a cost of 4c per cu. yd., and have also seen them working at 28c per cu. yd. At that cost, when one has only 35c gravel, there is not much profit.

*Mr. A. Bement, M. W. S. E.:* With reference to the Snake River and the recovery of its gold, it appears to me that the amount of gold is overestimated. The gold in the black sand of the Snake River seems to be a favorite thing to exploit, and there have been a good many dredges built, put to work, and abandoned there. The prevailing excuse given for failure is the difficulty of recovering the gold from the sand, but in my mind there is a question whether there is as much gold in the river

as many people believe. Then, too, I think it is largely localized at the heads of bars, and this leads some people to anticipate the presence of a very much greater quantity of gold than there actually is.

In reference to washing of debris down from the Sacramento and San Joaquin rivers, I am curious to know how far the material was carried—whether to San Pablo Bay, or as far down as San Francisco Bay, or if it deposited in Suisun Bay.

*Mr. Storey:* The question was quite thoroughly threshed out at the time this matter went to the courts. The miners contended that practically none of the debris got down as far as was claimed, and the farmers contended that practically everything that was deposited came from the mines. As a matter of fact, farming operations do cause material to be washed into the streams, and the streams silt up, and Suisun Bay and San Pablo Bay contain very large amount of material that has been brought down from the farming lands. Feather River empties into the Sacramento River possibly 30 miles above Sacramento City. Near the mouth of the Feather River a break occurred in the levee and material was carried out across the land immediately inside the levee. I examined the material personally, and there was no question but that it came from the same gravel-bank high up in the Sierra Nevada mountains that was washed with a hydraulic nozzle. It had the peculiar appearance that goes with hydraulic debris rather than farming debris, and having been carried that far there is no question in my mind but that a large amount of the material in the bed of the Feather River at that point has been carried on down in the succeeding years; and while it may not have floated out to the water in the form of silt, it has been rolled along the bottom of the river until it succeeded in silting out into Suisun Bay, and it will ultimately get to San Pablo Bay.

In addition to this sand and injurious material that fills up the beds of the streams, there is a certain amount of silt which is very light and flocculent—an actual clay—that comes from these beds and is washed by the giant into the streams. Undoubtedly that has been carried not only into San Pablo Bay but out to the Pacific Ocean. I made many experiments with that material to find how long a time it took it to settle and what motion of water would keep it in suspension, and I was amazed to find that it would not sink unless the water was kept absolutely still. For many years the water in the Sacramento River all the way down to San Pablo Bay was very deeply tinged with the color that came from this flocculent matter of the clays, and the red soils as distinguished from the sand and gravel of the deeper diggings, and I feel satisfied that the hydraulic mines sent injurious material down into the bays and rivers.

## DESIGN OF STEEL MILL BUILDING.

F. E. DAVIDSON, M. W. S. E.

*Presented, March 9, 1910.*

The new Open Hearth building constructed by the Illinois Steel Company at its South Works in 1903 and 1904 is, in round numbers, 160 feet in width by 1,125 feet in length, and is 55 feet from the main floor to the bottom chord of the roof trusses. The column spacing, system of roof truss bracing, etc., is shown in Fig. 1. The columns of the building are spaced 37 feet 6 inches center to center in the length of the building, with roof trusses located 12 feet 6 inches center to center, two of each set of three being supported on a ridge strut, or more properly, a latticed girder supported by the main columns of the building. The rather heavy loading on the crane runways, as well as the height of the trusses above the floor, required that unusual care be taken in designing the bracing for the building.

The officials of the Illinois Steel Company, who were familiar with the design of other large open hearth plants, were determined that the mistakes made in other designs were to be taken advantage of in this case, and that a model steel mill building would be designed and erected. The instructions given to the speaker, who designed the steel work for this building, were: "Design the building so that it will be rigid not only against wind strains, but in all directions from the impact of the moving crane girder loads, assuming that traveling cranes were loaded to their maximum capacity and were traveling in any direction at the maximum speed." In designing the steel for the building, steel in tension was figured at 16000 lb. per sq. in., and in compression at 16000 lb. per sq. in., reduced by the well known

70L  
formula of  $\frac{70L}{R}$

In figuring the bracing for the building, the following assumptions were made: first, that the total maximum pressure of the wind against the building would be 15 lb. per sq. ft. Second, that the roof trusses for the building were to be designed as a rigid body, and that therefore it could be assumed that all of the wind load on the roof truss itself, as affecting the columns of the building, etc., could then be assumed to be a horizontal force acting at the top of the columns. This reaction or horizontal force, as well as the wind pressure against the sides of the building, and also the maximum end reaction of the crane girders from the im-

part of the moving loads, all had to be provided for. Columns were assumed to be fixed at both ends, and in order to provide clearance for the ends of the traveling cranes, and to avoid as much as possible the eccentric loads on the columns from the crane girders themselves, the cross section of the column above the crane girders would of necessity be much less than the cross section of the columns below the crane girders. Therefore the moment of resistance of the upper section of the column being so much less than the moment of resistance of the base section, it was assumed that one-fourth of these combined stresses would be taken by the upper section of the column in bending, by means of the knee brace to the roof trusses; and the roof truss itself. The bottom chord of the trusses was to be so well braced that each of the three main columns across the building could then be assumed to take one-third of this one-fourth of the combined stresses above referred to. It was then assumed that the lower section of the outside column would take care of three-fourths of the combined wind stresses, as well as one-half of the maximum stress of the crane impact. It was assumed that the upper section of the center column would take care of the same stress as the outside columns. It was also assumed that the lower section of the center columns would take care of one-half of the bending stresses from the combined maximum reactions caused by the crane girder impacts. In designing the bracing, as well as the column sections, it was assumed that the crane girders in the two sections of the building would be directly opposite each other when producing their maximum stresses in any direction, and this maximum stress from both cranes, was combined with the maximum wind stresses.

In figuring the side bending moments of the main girders themselves, as well as the maximum side reaction due to the moving crane loads, the well-known formula for work was used,

$$WV^2$$

viz.:  $E = \frac{WV^2}{2G}$  where  $W$  is the total moving load,  $V$  the maxi-

mum velocity and  $G$  the acceleration due to gravity.

#### DISCUSSION.

*The Chairman* (Mr. T. L. Condron), observed that with reference to the mill-building of the Illinois Steel Co., some questions had occurred to him in regard to the assumptions made in the design of the crane-girders and the columns supporting them. He did not know whether it was usual for such girders and columns to be designed to resist the movement of crane-loads at a velocity  $V'$ , which was probably unknown, and wished to know how these forces could be applied to the girders and columns, unless the cranes were run against a positive stop.

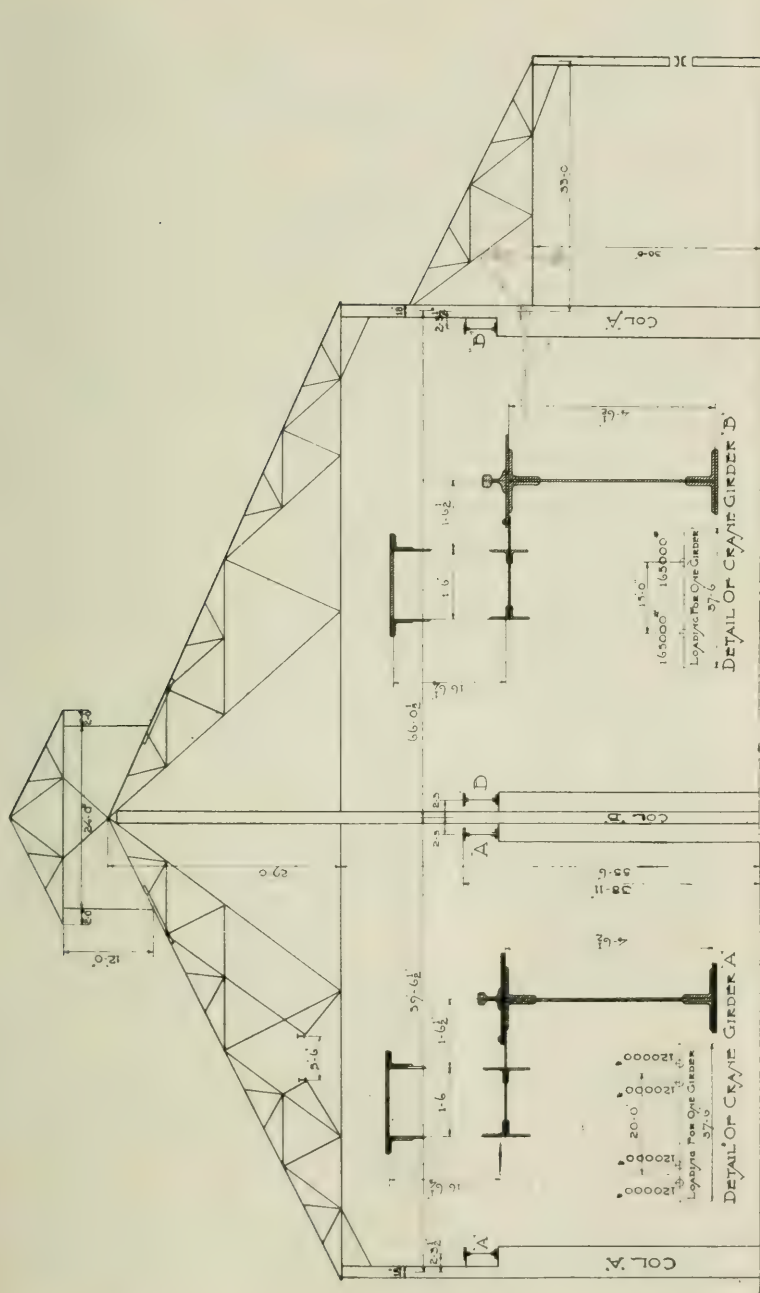


Fig. 1. Cross Section of Steel Mill Building.

Mr. Davidson, thought this might occur through reversal of the current.

The Chairman observed that reversal of the current would have only such effect as would be taken care of by the friction of the wheels on the rails. It was his impression that it was customary to design these girders to resist a lateral force equal to one-fifth of the dead and live loads of the crane.

Mr. Davidson stated that the assumption made by him gave an equivalent of about two-fifths of this load.

The Chairman thought this would depend on the velocity, and wished to know if the use of frictional resistance was not a more common method than the *vis viva* formula.

Mr. Andrews Allen (Past President), stated that both methods were used; that frequently, in designing girders and columns for high-speed cranes, especially electric cranes, he had taken the maximum acceleration under the maximum load from the power and the gearing of the motor, had figured from that the horizontal force applied, and had thus arrived at the reaction against the girder or bracing, upon the assumption that it would give the actual working maximum, since no man in operating a crane would reverse the current and bring the load to a sudden stop. On the other hand, however, he stated that in railroad work a train was often brought to rest by sliding the wheels on the rail, and, therefore, he always figured on a coefficient of two-tenths.

Mr. Gordon F. Dodge, M. W. S. E., in speaking of Mr. Allen's remark that no man would reverse the current and bring the motor to a sudden stop, related an experience in South Chicago in which the operator lost control of the motor. In this case the front wheels of the crane had passed over the end-straps and the crane had hung by the rear wheels.

The Chairman suggested that the designer would be justified in working out the structure to the elastic limit rather than design for such abnormal conditions, especially since he had to pay the market price for steel.

Mr. Davidson, in referring to the question of cost, stated that the cost of the structure was a little less than that of a pin-connected truss.

The Chairman thought Mr. Davidson should have to make comparison with something a little more recent than the pin-connected type of mill-building, but that of course other questions would enter into the construction of a mill-building besides the particular loads under consideration. He was much impressed by the size of the column-sections.

Mr. E. N. Layfield, M. W. S. E., asked if the pamphlet of the Weather Bureau, from which the velocity of 15 lb. per sq. in. had been deduced, gave the velocities of high storms,—say those of 60 to 80 miles per hour.

Mr. Davidson replied that the highest velocity recorded here was 90 miles per hour, and that from this a maximum pressure of 19.2 lb. was deduced.

Mr. Allen desired to know on what area the observations were made, and also what assumption was made or what formula was used in resolving horizontal pressure into vertical pressure on the roof.

Mr. Davidson explained that it would require reading the entire pamphlet to explain the experiments made and the methods used in determining the values of these pressures. He then read from Section 14, "Relation of wind velocity and pressure," the following paragraph:

"The relation between mean pressure of the wind against exposed surfaces and the corresponding wind velocity has never been worked out with entire satisfaction. Nevertheless rather better results can be obtained by using such facts as are known

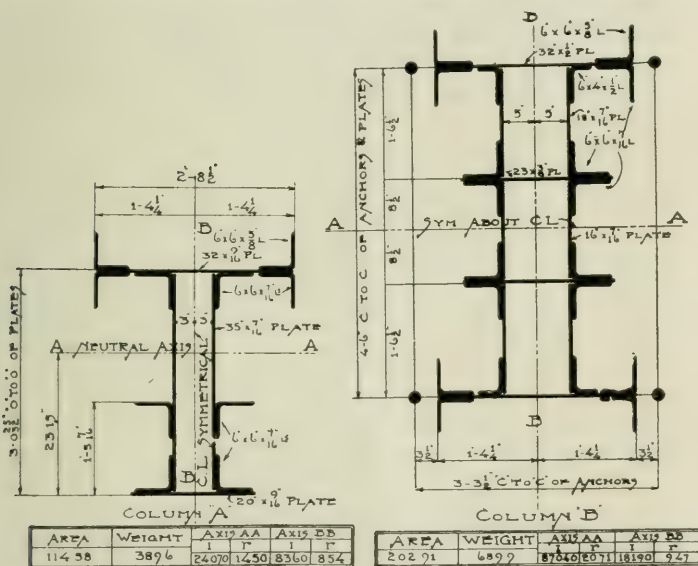


Fig 2. Details of Columns in Fig. 1.

than to attempt to measure the wind pressure directly. Experiments were made by this Bureau to determine the relation between wind velocities and pressures for certain limited conditions by exposing squarely against the wind variously sized plates of from four to nine square feet of surface. The deflection produced in springs of known strength by the pressure was continuously recorded by a pencil marking upon a revolving cylinder of paper. At the same time and on the same sheet of paper was also electrically recorded the velocity of the wind

as indicated by an anemometer exposed near the pressure plate.

"From these experiments, taking into account the corrected velocities as given by the above table, it is found that wind pressures are not so great as generally computed heretofore, and are quite accurately given by the following equation:

$$P = .0040 \frac{B}{30} S V^2$$

P=pressure, in pounds avoirdupois.

S=surface, in square feet.

V=corrected velocity of wind, in miles per hour.

B=height of barometer, in inches.

"For stations near the sea level where the barometric pressure does not differ much from 30 inches, the ratio  $\frac{B}{30}$  need not be considered. For elevated stations, however, with barometric pressures ranging one or more inches below 30 inches, the effect of this must be considered."

TABLE OF WIND PRESSURE (POUNDS PER SQUARE FOOT).

Indicated Velocity— miles per hour.	+0	+1	+2	+3	+4	+5	+6	+7	+8	+9
0.....	.....	.....	.....	.....	.....	0.104	0.144	0.190	0.243	0.303
10.....	0.369	0.433	0.511	0.586	0.666	0.762	0.853	0.949	1.05	1.16
20.....	1.27	1.38	1.50	1.63	1.76	1.90	2.04	2.19	2.34	2.48
30.....	2.64	2.81	2.98	3.14	3.32	3.50	3.67	3.87	4.04	4.24
40.....	4.44	4.64	4.84	5.07	5.27	5.51	5.72	5.93	6.18	6.40
50.....	6.66	6.89	7.12	7.40	7.64	7.88	8.14	8.43	8.69	8.95
60.....	9.22	9.49	9.76	10.1	10.4	10.6	10.9	11.2	11.6	11.9
70.....	12.2	12.5	12.8	13.1	13.5	13.8	14.1	14.4	14.8	15.1
80.....	15.5	15.8	16.2	16.5	16.9	17.3	17.6	18.0	18.4	18.8
90.....	19.2	...	...	...	...	...	...	...	...	...

*The Chairman* in referring to this bulletin, stated that observations of this kind had been criticized on the ground that the recording-device failed to record accurately, the velocity of the wind; on account of the peculiar action of wind-force the device was liable either to run ahead of the wind-velocity or lag behind it, and might be rendered inoperative by the force of a hurricane wind.

In the matter of city ordinances, reliance had been placed on the classical experiments of Sir Benjamin Baker. These experiments had been made with reference to wind-velocities at the Firth of Forth bridge, where high winds were common. Nevertheless, it was expected that the city structures would be designed in accordance with Sir Benjamin Baker's equation.

Under present requirements, a permit could not have been obtained for designing this mill-building for a pressure of 15 lb. per sq. ft. He believed that in Sir Benjamin Baker's experiments, pressures as high as 60 lb. had been recorded.

*Mr. R. M. Gerety*, M. W. S. E., observed that the Royal Commission appointed to investigate the conditions at the Firth of Forth bridge had determined from experiments on large surfaces that 55 lbs. per sq. ft. was about the limit of wind-pressure, and that the bridge had been designed for practically this pressure. He believed that Mr. Baker, after taking observations during the construction of the bridge, had concluded that an allowance of 20 lb. over a large surface was sufficient.

*The Chairman* thought the surfaces used in these experiments were about 20 ft. square.

He was surprised that nothing had been said about the frictional resistance of these girders in determining the lateral load on the girders and columns. The condition had been introduced of a combination of wind-load of 15 lb. per sq. ft., with the maximum condition of two cranes in the same line, but the speaker (*Mr. Davidson*) had not said whether the same unit-stress had been used, or a decreased unit-stress. Maximum wind-stresses occurred infrequently, and operation of the cranes would probably be suspended during a hurricane wind. He therefore thought it safe to use a higher unit-stress where wind loads were involved.

*Mr. Davidson* stated that the same unit-stresses had been used. In addition to figuring the structure for these unusual conditions, 1-16 in. had been added to the thickness of every piece of steel to provide for corrosion.

*Mr. Wm. G. Langenheim*, M. W. S. E., asked if provision had been made for temperature-stresses.

*Mr. Davidson*, replied that temperature-stresses had not been provided for in the cranes; that temperature-stresses resulted simply in raising the temperature of the steel, and it was not customary at the present time to figure it in long sections.

*The Chairman*, was of the opinion that the expansion-joints, originally provided every few hundred feet in the large buildings at Homestead, had since been riveted solid.

*Mr. Langenheim* observed that the objection to expansion-joints was that they localized the expansion and resulted in gaps in the rail. He had designed a building 400 ft. long without expansion-joints.

*The Chairman* suggested the use of a split joint to overcome the difficulty mentioned by Mr. Langenheim.

*Mr. Davidson* stated that he was greatly interested in the subject of wind-bracing; that he had examined all the engineering literature with which he was familiar, but had not found any complete academic explanation of this question. He also stated that in pre-

senting this paper he had hoped to call forth a paper on the proper method of arriving at these strains.

*Mr. Langenheim* thought it was better to assume a high wind-pressure with a high unit-stress, than a low wind-pressure with a correspondingly low unit-stress. While the results were apparently the same, the first method possessed the advantage of showing any reversal of stress.

He stated that he had used the same method as *Mr. Davidson*, in assuming the wind-pressure on the roof as a horizontal force at the tops of the columns. On the assumption that the deflection of the columns was the same, the force taken by each column depended directly on its moment of inertia. Taking three columns in a row, if the middle column was heavier and stiffer than the other two, it would take the greater part of the load, and should be designed for it. The same condition was presented in the construction of skyscrapers.

*The Chairman* regretted that nothing had been said particularly about the column-sections, and said that he supposed there was nothing unusual about them except their size.

*Mr. S. Lee Pierce*, JUN. M. W. S. E., stated that there were 4,500 tons of steel in the mill-building, and in order to avoid getting the trusses for the entire building first, the building had been divided into three sections. All the material for the first section had been turned out of the shop before work was started on the second section.

*The Chairman* then exhibited lantern slide views, illustrating a building designed for the Chicago & Eastern Illinois Railroad Co. several years ago, and somewhat similar in construction to the one under consideration:

The main building had a 75 ft. crane-span designed to carry a crane of 100 tons capacity. The crane carried two trolleys. Another smaller crane had been added later, carried on the same columns by brackets. The columns had been designed in much the same way as those in the building under discussion, except that one-fifth of the dead and live loads of the crane had been carried into the columns. With the same arrangement of columns, the building had since been more than doubled in length. There was the same arrangement of gusset-plates to attach the roof-trusses rigidly to the columns. Very stiff bracing had been provided in alternate panels. The columns were H-shaped, connected on the sides with large battens.

*Mr. Davidson* asked if any engineer, in designing columns, had taken into account the internal stresses due to unequal tightening of the anchor bolts. He thought this might bring about stresses that the designer did not know anything about.

*The Chairman* did not think this could be considered in designing, as it was necessary to assume that work would be erected in accordance with plans and specifications, and such errors would have to be taken care of by the factor of safety.



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## UNDERPINNING A FACTORY BUILDING.

F. E. Davidson, M. W. S. E.

*Presented March 9, 1910.*

The circumstances surrounding the work of underpinning the building at Nos. 385-393 Fifth Avenue, which made it necessary to construct an entirely new foundation after the building was occupied, were so radically different from the ordinary conditions of building-construction that a review of the conditions and resulting effects on the building is required before a proper understanding of the case can be had.

The property is located on the east side of Fifth Avenue, near Harrison Street, has a frontage of 90 ft. and extends back 100 ft. to the alley in the rear. The improvement of the property consists of two buildings. The building on the south side of the lot was built shortly after the fire of 1871, and is very light in construction as compared with the factory-building of more recent date. The building on the north side of the lot at the time it was constructed, followed the type of construction known as the modern mill-construction. The floor joists are 9 in. by 16 in. Georgia pine timber, supported at the center of the building on steel girders, which in turn are carried by a row of cast-iron columns, the north wall ends of the floor joists being carried directly on the brick wall of the building. The south ends of the floor-joists south of the center row of columns are supported by I-beam girders running parallel to the dividing-wall between the old and the new building. The columns supporting these girders rest on a cantilever foundation, thus making the new building structurally independent of the old building, both of which are five stories in height. At the time the work was done the buildings were occupied by the Troy Laundry Machinery Co. The new building was erected for the use of that company, and was designed to carry rather heavy loads, the first floor being designed for a live load of 400 lb. per sq. ft., and the upper floors for 200 lb. live load per sq. ft.

The foundation for the building as originally constructed consisted of piles driven to hardpan. These piles were mixed wood timber, 14 in. at the butt, tapering to 8 in., and varied from 50 to 55 ft. in length. Piles were driven to a depth of 50 ft. below city datum, and were capped with 5 ft. of concrete.

The City of Chicago issued the building-permit for the building early in October, 1902, the work was started at once, and the building was completed and turned over to the Troy Laundry Machinery Co. early in April, 1903. Their plant, which consists of very heavy machinery, was moved into the building at once. These machines consist of lathes, planers, boring machines, drills and grinders, vary in weight up to approximately 2 tons each. When the plant was in

August, 1910

operation the building was given a vibratory motion of unusual magnitude.

Soon after the new building was occupied, the basement floor began to show evidences of subsidence of the soil underneath it, and cracks began to develop in the concrete floor north of the center row of columns. The settlement increased daily, and it became necessary to fill the area affected to make the basement at all useful. To keep ahead of the settlement of the basement floor level, all of the cinders from the two boilers of the Troy Laundry Machinery Co. were used daily, besides a large quantity obtained from other sources. In January, 1904, the main sewer of the new building, which crosses through the center of the basement, was ruptured by the settlement that had taken place, making it necessary to move this sewer and place it upon the concrete footing of the north wall of the building. Up to February 6th, the only sign of settlement was about 1-in. in connection with some of the center columns. On that date the owner of the property—Mrs. Amelia E. Winterbottom—employed Mr. John H. Sutter to make a thorough investigation of the premises, and to take entire charge of any repairs or strengthening of the foundations that might be required.

A careful examination of the premises showed that the settlement had reached such a magnitude that the building would soon be unsafe, and a thorough investigation was begun to ascertain, if possible, the cause of the disturbance. It was found that the floor north of the center row of columns had settled as much as 14 ft. below its original level. This cavity had been filled with cinders and water, which had either followed the piles into the hole or had come from a sewer on Fifth Avenue which was too small to take care of the storm-water sewerage of the vicinity. The water had thoroughly saturated the surrounding soil, and greatly aggravated the condition. The slope of this settlement was from the front to the rear of the building, and reached a maximum depth at a point about 30 ft. from the rear wall. The writer, at this date, was asked to assist in the investigation and to design the new supports for the building.

From data and evidence gathered, it was found that the City of Chicago had a 7 ft. water-tunnel in that vicinity known as the South-West Land Tunnel, and it was natural to assume that it had become damaged in some manner, and had caused the scouring away of the soil under the building. The city authorities reluctantly admitted that if the plans of the City Engineer's office were correct, the tunnel in question lay diagonally across the lot on which the new building had been erected. This fact, while informing those in charge of the work as to the cause of the settlement, made the situation more serious, as it was then self-evident that some of the piles driven for the foundation of the building had penetrated the tunnel, and that the water rushing through it had carried away the soil under the building and undermined it. A careful investigation showed that the top of the tunnel was at a point about 60 ft. below the grade of

Fifth Avenue, or about 46 ft. below city datum, and about 5 ft. higher than the average depth of the points of the foundation piles.

An abandoned working-shaft, which had been used in the construction of the tunnel, was found on the west side of Fifth Avenue, and this was immediately uncovered to permit a diver to make a descent to examine the condition of the tunnel. He reported that both the east and west drifts were filled with mud so high as to make it impossible for him to find the eye of the tunnel on either side. As the tunnel was filled with mud and debris, it was impossible to determine how greatly it was damaged; but it was certain that the

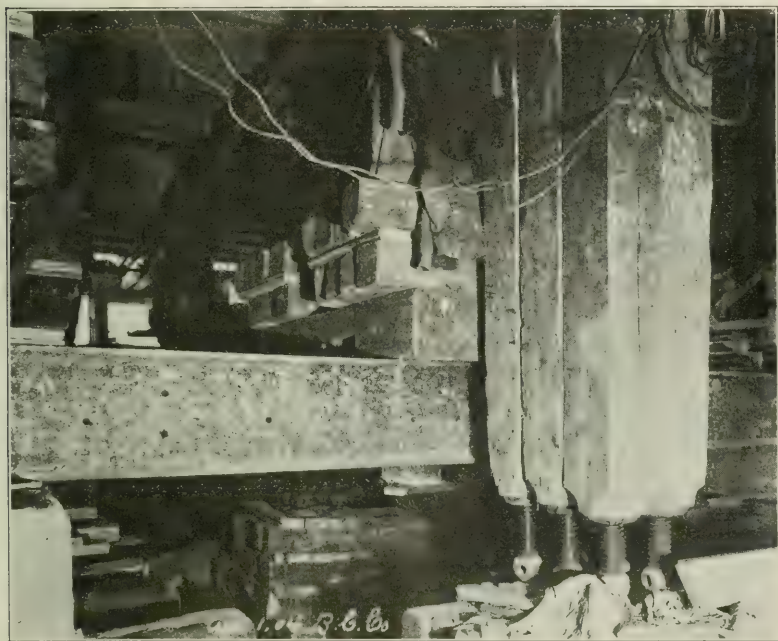


Fig. 1. View Showing System of Underpinning Used in This Work.

proper conclusion had been drawn as to the cause of the settlement.

It was clear that the soil surrounding the foundation piles had become saturated with water and rendered too soft to give the required lateral resistance to hold the piles in place, and that without this support they would buckle and endanger the safety of the building. It was evident that some means must be speedily provided to control the building in case the foundations began to fail. Shoring material—including jack-screws, timber-drums, blocking and beams—was provided, and the work of securing the columns already affected was immediately started. The presence of the cast-iron columns carrying such heavy loads made the shoring a difficult prob-

lem. The steel girders supported by these columns rested on cast-iron lugs, and the danger was that any excessive unequal settlement of the columns would cause the lugs to crack and give way. To prevent failure in this manner, the entire load on the girders was removed from the columns by placing drums on each side of the columns on each floor to carry the weights supported by the girders above. The drums about the columns in the basement were carried upon heavy I-beams about 25 ft. in length, the ends of these beams resting on jack-screws supported on timber cribs. Provision was also made for relieving screws, to carry the load while any crib was being rebuilt or shifted, if necessary. All of the walls of the building, any portion of which was above the line of the tunnel, were placed on short drums. The work of placing these jack-screws was carried on day and night.

During the operation of setting the screws, it was found by the system of levels established that the walls and columns were very slowly settling. It was then decided to extend this shoring to cover a greater area, as there was a very serious lateral movement of columns and foundations combined with the settlement, to as much as 1 in. per day in many instances, and it indicated that the piles were buckling and leaning toward the holes in the tunnel. During the time occupied in putting the jack-screws in place only an inconsiderable settlement of the building had occurred, notwithstanding the fact that the soil toward the front of the basement continued to settle at the same rate as previously; but shortly afterwards a sudden and rapid subsidence toward the back part of the basement started. As this was in a location where there had been no great settlement, and as the rate of this settlement was practically constant, very serious doubts were entertained by those in charge as to their ability to save the building. It became necessary to increase the bearing area by timber platforms, which were immediately put in place. These platforms were of 12-in. timbers and gave a total width of 30 ft. But even with this additional provision the settlement continued at the same rate as previously. It was evident that the walls about the elevator shaft and stair-well were directly above the center of disturbance and had become seriously cracked by the stresses due to the unequal settlement of the foundation, and now began to crush and crumble. By actual measurement the settlement of the pile foundations of these walls and the footing of the dividing wall in the rear was 7 ft. 2 in. from February 12th to March 2d. The settlement of the south crib supporting the shoring-beams under column No. 4 was 14 ft. in the same length of time. It was decided that it would be impossible to hold these walls longer, and their removal was deemed necessary for the preservation of the floors.

The work of removing these walls was pushed so rapidly that within 56 hours after the wrecking was started all the brick-

work in the rear of the new building which was considered dangerous was removed. The dividing wall in the rear was removed at this time, but as the wrecking of portions of the walls in the new building about the elevator-shaft and stair-well was completed, it was found that the old wall in the rear was very seriously cracked, warped, and otherwise damaged. It was considered possible to hold this wall, but it was thought that the additional expense would not be justified, as in the end the wall would have to be rebuilt, and therefore it was also removed.

Early in the operations of getting control of the walls, the

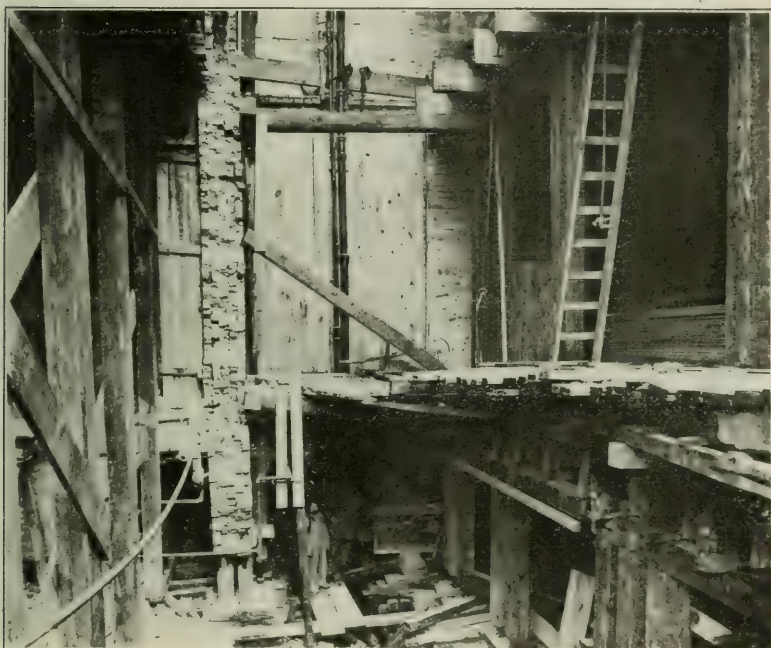


Fig. 2. View of Building After Stairwalls Had Been Removed.

settlement caused the breaking of one of the flanged-joints of the steam-main of the battery of boilers, which was located just south of the dividing wall in the rear. A steam pressure of 125 pounds per sq. in. was maintained on these boilers. Fortunately warning was given in ample time to shut off the steam, and none of the men engaged in the work were injured. The further use of these boilers was impossible, and a temporary plant of two 100 h. p. firebox-boilers was installed in the alley for immediate use.

As soon as the rear wall started to settle, the footings of

the center row of columns in the new building also settled rapidly. Before the entire load was taken off of the pile-piers originally supporting the columns, a settlement of over 4 ft. had occurred in the case of columns Nos. 2 and 4, while the other columns had settled less, ranging from that down to a few inches. These figures only measured the settlement of the footings of the columns before the loads were transferred to the screws. After that was done there was no accurate method of measuring it. So uniformly and carefully was the work of turning the screws carried on, and the levels of the various parts of the building



Fig. 3. View in Basement While Caissons Were Being Constructed.

adjusted, that no dangerous or unequal settlement of the superstructure occurred. The building was constantly under control and held in a fixed position, so that the occupants were able to go ahead with their work, all of the shafting and other parts of the machinery being kept in line and running smoothly. The only time that the Troy Machinery Co. was forced to shut down its plant on account of this work was during the time of the temporary installation of the boilers in the alley.

The plan adopted for the new foundation was to sink caissons of adequate size, properly placed to support steel girders for carrying the walls and columns, these girders to be encased

in concrete to prevent corrosion. Before the plans for the location of these caissons were drawn, the City Engineer's office was requested to prepare a plat or survey showing the exact location of the tunnel with respect to the building. The caissons were planned to be located on each side of the water tunnel, so that at least 4 ft. of soil would be between the outside of the caisson and the brick-work of the tunnel. The caissons varied in diameter from 4 ft. to 6 ft., and were to be sunk to bedrock—a distance of about 80 ft. below city datum. The water-tunnel is in hardpan. Since it was planned to leave 4 ft. of this hard clay between the caissons and the outside wall of the tunnel, it was thought that the caissons could be excavated by the usual method adopted in Chicago for such foundation work, and without removing the head of water in the tunnel.

Owing to the failure of the water-tunnel, the materials overlying it were completely saturated by the water escaping from the tunnel under pressure, and it proved very difficult to sink the wells in the manner adopted. The soil to be excavated had become exceedingly soft, and the entire mass of earth under the building seemed to move bodily toward the supposed location of the holes in the tunnel. The work of sinking the wells was started on the one shown on the plans as No. 2, and it was excavated to bedrock without much difficulty other than that experienced from the exceedingly soft soil encountered and the water which was prevalent throughout the basement. As there seemed to be some doubt as to the exact location of the water-tunnel, lateral borings were made in this hole before it was filled with concrete; but on account of the obstruction caused by the piles of the surrounding piers, no favorable results were obtained.

Well No. 3 was tried next, and its location being in the center of one of the places of greatest settlement, it was a very difficult task to sink it through soil which was so thoroughly saturated with water. Before any progress could be made it was necessary to sink a watertight cofferdam through the cinders used to fill the sunken place. This proved very difficult on account of the depth of the water and cinders. When the original soil was finally reached, it was so soft that it swelled up from the bottom of the well, and it was necessary to drive lagging several feet ahead of the excavation in order to make any progress whatever. The excavation was discontinued many times on account of the dangerous condition and unequal settlement of the lagging above. The pressure of this soft clay was greatly increased by the pressure of the cribs supporting the shoring-beams under the columns on either side of the well. These cribs at intervals settled at the rate of one foot per day during the time occupied in excavating the first 25 ft. of the well. The unequally distributed pressure upon the lagging of the well caused by the proximity of these cribs made it necessary several times to reinforce the

lagging before excavation could proceed; and by the time a depth of 40 ft. below city datum was reached the entire well had been laterally displaced toward the tunnel, a distance of about 2 ft. The shape of the well had changed from that of a circle to that of an ellipse, the smallest axis of which was about  $4\frac{1}{4}$  ft. The reinforcing of the lagging was accomplished by using small rings and filling out with blocks, thus reducing the diameter, the intention being to restore the well to the proper size when filling with concrete.

The clay found at a depth of 40 ft. below city datum was considerably firmer than that above, but, as it was found only on the side farthest away from the tunnel, it made the conditions worse, since the lagging on that side ceased settling, while that on the other side kept on going down. It was evident, from the way this stratum of firm clay was situated, that the well was located at the point marking the angle of slope made by the clay as it flowed on entering the tunnel. The continued unequal settling of the lagging made it necessary to anchor it and the supporting-rings to the floor-beams of the first floor. At a depth of 43 ft. below city datum, water broke through from the bottom of the hole on the side nearest to the tunnel. The well filled so rapidly that the workmen could not be taken out in the usual way, but floated to the top, where they were dragged out. This rapid filling of the well to about the level of Lake Michigan indicated very clearly the source of the water. After this accident the hole was filled with sand to save it from collapsing, and was abandoned.

This mishap proved that either the tunnel was not correctly located, or that the clay figured upon to be between the well and the tunnel was not sufficient in thickness to withstand the pressure of the water at that depth. To sink the wells nearest the tunnel, either the pneumatic process would have to be resorted to or the tunnel must be pumped out. The problem of removing the water from the tunnel caused some apprehension on the part of those in charge of the work, as it was feared that the removal of the pressure exerted by it would again start the settlement, which at this time had shown signs of ceasing. However, as the tunnel would have to be repaired ultimately, it was decided to remove the water at that time, and thus save the delay and expense of using the pneumatic process.

The gate at the shaft in this tunnel at Peck Court and the Lake Front park was on the lake side of the shaft, and consequently, when closed, the entire pressure due to the head of water it was under would be against the guides. It seemed doubtful that these guides could withstand this head and the gates still be tight enough to permit pumping the water from the tunnel. An attempt was made to close the gate, the intention being to reinforce it by means of jack screws extending across to the

other side of the shaft. When the attempt was made to close the gate, it was found to be so twisted from some previous misuse as to be absolutely useless, and no further attempt was made to use it. A heavy timber bulkhead was built to be placed against the west heading opposite the gate. This bulkhead was lowered into the shaft and set in place by a diver, the shaft being partially filled with clay to stop small leaks. After it was set it was firmly held in place by jack-screws bearing against the opposite side of the shaft.

The necessity of placing this bulkhead on the land side of the shaft removed all access for pumping out the water in the tunnel between the shaft and the building. To accomplish this an 8 ft. shaft was sunk on Sherman Street, about 300 ft. east of the rear of the building. This shaft was sunk 10 ft. south of the tunnel, and was connected to the tunnel by a 4 ft. cross-cut. In the meantime an attempt was made to close the gates in the water tunnel on the west side of the Chicago River, which was necessary to shut off the water from the Chicago Avenue Pumping Station, but it was found that in doing this the Western Electric Co.'s supply of water would be entirely shut off, as they had been securing their water supply from one of the shafts which would be opened for the pumping operations. They had secured this right by special concession of the City Council, and at the time they made connections with the shaft, all other connections with the city water mains had been taken out, and these had to be restored before the gates could be closed. Special pipe-fittings were required for this change, and it took several weeks to secure them. The entire delay to further work on the abandoned wells at the building was practically three months.

In the meantime Well No. 4 was tried, but it had to be abandoned on account of the soft mud encountered, and the water coming in so fast it could not be taken care of by pumps at the building. This well was situated between two pile-piers. At a depth of about 20 ft. below city datum it was found that the piles of these piers had deflected so much from the vertical line in driving, that nine of them were found within the circle of the well. The water encountered was clear and cold, came into the well from alongside of the piles, and was evidently from Lake Michigan. In all probability the piles which it buried were in contact with the tunnel, so that no further attempt was made at excavation in this well until the water was removed from the tunnel. Work, however, was pushed on other wells farther away from the tunnel, and a number of them were completed before the water was entirely removed from the tunnel.

The clay dug through was in all cases very soft. In the worst wells the workmen were compelled to stand on short planks in order to work effectively. The temporary connection with the city water-mains required by the Western Electric Co.,

August, 1910

and the closing of the gates in the shaft on the west side of the river, were completed June 18th. The two pumping-plants which had been provided— one at the temporary shaft at Sherman Street, and the other at the Fifth Avenue shaft—were put in operation June 20th. As the water was pumped out, great care was taken to keep it at the same height in both shafts, to prevent any movement of the shaft mud in the tunnel, due to difference in head in the two shafts.

Work on well No. 3, which had been abandoned March 26th, was resumed on June 21st. The diameter of the well was increased from 5½ ft. to 6 ft. This was done to give an opportunity to straighten the well, which was in very bad condition—the old lagging was out of plumb and the whole well was out of position. It was a difficult matter to keep the new work in proper place. Sand was used to fill in the space created back of the new lagging by the movement of the old well toward the tunnel. This cylinder was completed on July 6th. When passing the tunnel it was found that the lagging only just cleared the brick-work of the tunnel itself.

Work was resumed on well No. 4 on August 1st, and was completed August 15th. This well overlapped the tunned about 18 in., and this part of the brick-work of the tunnel was removed when the well was filled with concrete.

All of the work of the concrete cylinders required to support the main girders was completed by August 15th, and on September 6th the remaining two of the row of columns in the center of the north building were landed on the permanent girder-supports. The last girders of the main system of girders—those under the walls about the elevator-shaft and stair-well—were completed on September 15th, and the rebuilding of masonry was started on September 28th.

The city water-tunnel is circular, and is 7 ft. internal diameter. The masonry consists of two rings of brick laid in cement mortar, making an outside diameter of approximately 9 ft. The central line of the tunnel intersects the north line of the lot under the north building at the curb line on the east side of Fifth Avenue, and the south line of this lot at the alley line in the rear of the building, thus making the path of the tunnel diagonal of the lot on which the new building was erected. The location of the tunnel in this position made it difficult to provide a system of girders to carry the columns, and have the concrete cylinders supporting the girders far enough away from the tunnel. All of the center row of piers upon which the columns originally rested were so near the lines of the tunnel that it was deemed best to provide girders which would support all of the columns of the building independent of the former foundations. The scheme finally adopted is shown on the girder plans. The grillage capping the concrete cylinders consists of I-beams rest-

ing on a circular plate equal in diameter to that of the cylinders. After this grillage was set, the space between the beams was filled with a very rich concrete. In all cases the steel girders rested directly on top of the I-beam grillage.

After the girders were set permanently, and the connections made, they were encased in concrete. As all of the steel work is below the finished basement floor, great care was exercised in the placing of this concrete to protect the steel work from corrosion, and in no case is any portion of the steel-work covered with less than 8 in. of concrete. It was necessary to provide cylinder foundations, originally carried on cantilever foundations, and these cylinders were made large enough to carry the old wall adjoining the columns on the south. The foundations of this dividing-wall had moved northward about 3 in. and were evidently damaged beyond repair. As the boiler-room in the rear of the old building had been entirely wrecked, it was necessary to provide a new positive foundation for boilers and columns of the building in the boiler-room. Two additional cylinders were sunk for this purpose, and were located in such position as to support a portion of the rear wall as well as the columns and the boilers.

The effects of the settlement due to the cave in of the tunnel were noticeable within a radius of about 100 ft. from the tunnel, but in no case were the settlements at this distance of a serious nature. In fact the settlement which occurred in connection with buildings back from the tunnel was no more serious than has occurred heretofore in connection with buildings adjoining a site where deep foundations have been constructed. The south wall of the south building, which is a party-wall between this building and the one adjoining it on the south, settled about 1 in. The columns on the south side settled from 2 to 4 in., depending on the distance of the columns from the tunnel. All that was done was to raise the columns to their original level and block them up.

It is a curious fact that through all of this disturbance the north wall of the north building, the front end of which is over the tunnel, showed no sign of settlement or movement during the entire work. This is a solid masonry wall, and serves as a party-wall for the adjoining property on the north. The foundation on which it rests consists of piles and concrete. There are about 100 piles in the foundation, and they are arranged in three rows parallel to the wall. In view of the settlement of other walls not so near the tunnel, it was assumed that this wall would settle also, and provision was made for three cylinders to be put in the front end of it. However, these cylinders were never constructed, as no settlement has ever taken place. After all of the cribs were in place, a force of men was put to work to clean out the tunnel. It was found that a great number of piles had penetrated the brick-work, and made the holes in the tunnel through

which the mud had flowed. These piles were not broomed in encountering the brick-work of the tunnel, and, in fact, were in no worse condition than would be expected after a pile had been driven through 50 ft. of firm clay. These holes were all immediately bricked up, the mud cleaned out, and the tunnel allowed to fill with water.

The City of Chicago paid the bills.



Fig. 4. View of Building After the Repairs Were Completed.

#### DISCUSSION.

*The Chairman*, referring to the Troy Laundry Machinery Co.'s building, asked if it had occurred to anyone to purchase it and then tear it down to save money.

*Mr. Davidson* stated that the total cost of repairing the tunnel and placing the building on firm foundations had been something like \$325,000. He could not say whether the probable cost had

been considered in advance. The work had been done and the city paid for it.

*Mr. Layfield* suggested that probably the cost could not be determined until work had progressed too far to be stopped.

*Mr. Davidson* called attention to the condition of two of the old working-shafts connected with the water-tunnel. Both the one on Fifth Avenue and the one near the Western Electric Co.'s plant had perforated covers, and through them a large amount of the drainage and street-sweepings continually fell into the tunnel.

*Mr. Pierce* observed that the load on caisson No. 5, with a diameter of 5 ft., 6 in., was 354 tons, while that on caisson No. 6, with a diameter of 4 ft. 6 in., was 525 tons. He wished to know why the larger caisson took the smaller load.

*The Chairman* suggested that this might be one of the caissons with a number of piles in it.

*Mr. Davidson* could not answer *Mr. Pierce's* question without examining his notes made at the time the work was done. The drawing shown was the one submitted to the city when the permit to reconstruct the foundation was asked for, and he was not sure that the caisson had been actually built to the dimensions shown.

*Mr. W. A. Hoyt*, M. W. S. E., speaking of the piles encountered in sinking some of the caissons, thought that they might have been deflected by striking the tunnel.

## WATER-POLLUTION AND WATER-PURIFICATION AT JERSEY CITY, N. J.

C.-E. A. WINSLOW.\*

*Presented March 16, 1910.*

The case of the Mayor and Aldermen of Jersey City, N. J., against Patrick H. Flynn and the Jersey City Water Supply Co., has been debated in the courts for a period of nearly four years, and during this time many questions of considerable interest have been raised in regard to water-pollution and water-purification. As a water-supply case, I think it will perhaps take rank in the history of the subject as second only to the great Chicago-St. Louis case.

The contract originally made between the defendants and the city provided that the works should be "so constructed and maintained by the contractor that the water delivered therefrom shall be pure and wholesome and free from pollution deleterious for drinking and domestic purposes during the time that Jersey City shall take water by the million gallons. If such works and supply are purchased by Jersey City they shall be delivered to said city as a completed operating plant free from pollution, as aforesaid." That was the real crux of the contract which was the subject for debate in the case. The question came before the courts as a result of the expressed desire of the city to purchase the water-works. It was provided in the contract that the city should have the right to purchase these works at a fixed price (\$7,595,000), if all the conditions outlined in the contract had been fulfilled; and the main question at issue was whether, first, the system was calculated to deliver pure and wholesome water, and second, if not, what deductions should be made from the contract price to make good the deficiencies of the supply. There were clearly implied provisions in the contract, and in understandings arrived at between the parties, that sewerage systems and sewage-disposal works should be "constructed or arranged for by the contractor to prevent pollution or to carry off pollution existing in the watershed."

The general conditions of the watershed can best be understood from the map (Fig. 1). The supply is derived from the Rockaway River,—one of the three or four large rivers that flow through the eastern part of New Jersey,—and the watershed above the reservoir has an area of about 122 square miles. On the river, near the reservoir, are three towns of some importance and also a number of villages, the rest of the watershed being occupied mainly by wooded land or by grazing and agricultural country. The principal towns on the watershed are Boonton,—

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right at the point where the river enters the reservoir,—Rockaway, and Dover; and a smaller settlement of particular importance is the little mining village known as Hibernia, on a stream which runs into the Rockaway River, near Rockaway. The population of Boonton is about 4,000; of Dover, 6,300, and of Rockaway, 1,600; total population on the watershed above Boonton is 169 persons per square mile. The slope of the watershed in the vicinity of the river is quite steep; in fact, in the town of Boonton and in parts of the town of Dover the river practically flows through the bottom of a sort of bowl, densely populated, and with every facility for introducing pollution into the stream. There were no public sewers in any of these towns. It was shown, however, in evidence introduced in the case, that a number of private sewers discharged from buildings into the stream and that the storm drains through the towns received considerable direct additions of sewage from privy-vaults and cesspools, which are of course bound to overflow at times. The village of Hibernia presented, at the time the suit was brought, a particularly interesting problem of this kind, in so far as it was an excellent illustration of the opportunity for polluting the stream by other ways than the direct discharge of sewage from sewers. Mr. Kuichling described conditions here as follows:

"The village or settlement of Hibernia is essentially a mining camp. It contains numerous small houses occupied by the miners and there are about 1,200 to 1,500 people there. Of that number, from 1,000 to 1,200 work underground in the mines during the day. While they are under ground their wastes mingle with the mine drainage water which is pumped to the surface and flows into the brook that runs through this little settlement or village. This village is in a narrow valley with steep hillsides. These houses are not of a high class of construction. They have, many of them, privies adjacent to runways for water—what would be called a water course or depression in the ground not containing running water. Some are only running brooks and rivulets. Pig pens and hen coops and stable yards generally, are located so that the drainage flows off readily. The water in the Hibernia brook is discolored and visibly and palpably polluted, both from what surface water there is as well as from the mine drainage. One of the mines delivers water that is as discolored and opaque as almost any city sewage."

These conditions, as to surface drainage, although a little more extreme than those generally occurring in Dover and Boonton, were typical of occasional local conditions in both those towns. They were continued, not only on the main river, but along the numerous tributary brooks, some of which are shown on the plan, but most of which are not shown. All these brooks and runways, whether they carried water in dry weather or not,

were for practical purposes a part of the stream; that is, from privy-vaults located near those brooks the pollution could be carried very rapidly, at times of flood, through these natural run-ways into the river. It was maintained by experts in the case that any privy-vaults and cesspools within 1,000 ft. of the bank of the stream or of the tributaries might constitute a source of pollution if they were not carefully looked after.

Analytical data showed the Rockaway River to be highly polluted all along its course, the pollution varying but being always considerable, and sometimes very considerable. The bac-

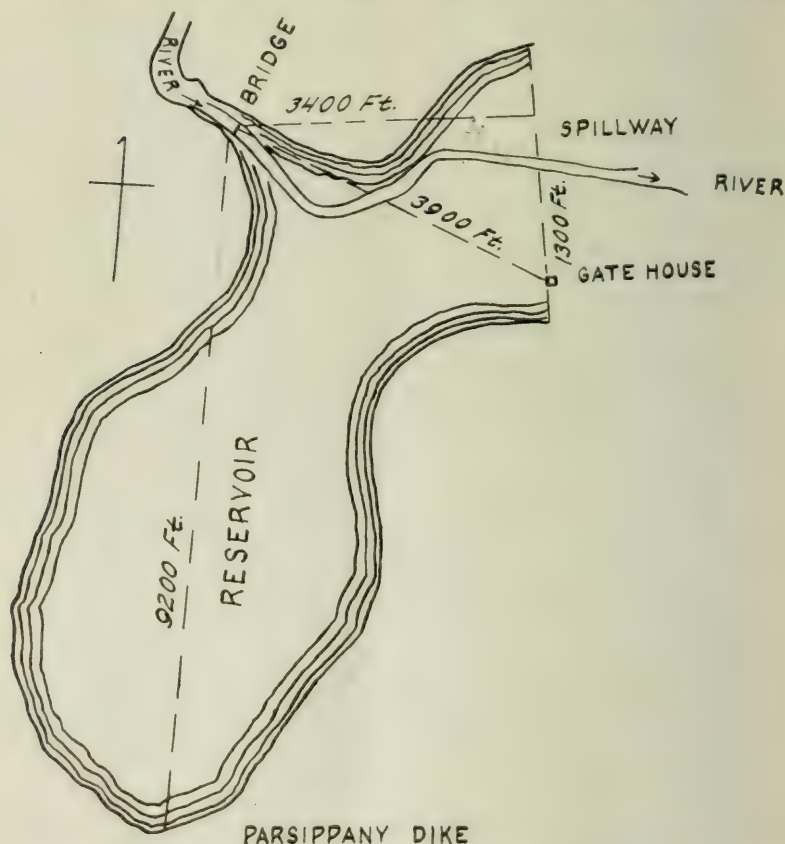


Fig. 2.—Reservoir for Jersey City Water Works.

terial count at the entrance to the reservoir ranged from a normal value of a few hundred up to 15 or 20 thousand after rain; indeed, the polluted character of the Rockaway River water was conceded on all sides. With the exception of minor discussions in regard to the extent of the surface-pollution, and the part



Fig. 1.—Watershed of the Rockaway River.  
 The prominent numbers indicate the points at which samples of water were taken for examination by experts for the city.

Courtesy of Nicholas S. Hill, Jr.



played by the agricultural land and the towns in causing that pollution, the main point of contest was in regard to the purifying-efficiency of the reservoir, which is a large one, as shown on the map. It is a little over two miles long and a mile wide, and the greatest depth is about 85 or 90 feet. It contains above the lowest gate from which water can be delivered, 7,300,000,000 gallons, or a supply for 146 days on the basis of the actual consumption of 50,000,000 gallons per day. At first sight such a reservoir would seem to offer ample facilities for self-purification. The water, however, entered the reservoir at one end and was taken out at the other side of the same end, as shown in Fig. 2. The direct line of flow was a comparatively short distance (3,900 feet), and the real question was as to the actual course taken by the water and the degree of purification effected. The discussion of the purifying efficiency of this mechanism is to my mind perhaps the most interesting phase of the first branch of this Jersey City case, and the opinion rendered in regard to it by Vice Chancellor Stevens is an admirable piece of sanitary writing. Few sanitary experts could make such a clear and forcible statement of the fundamental principles,—principles involving a considerable range of hydraulic and bacteriological problems. The Chancellor said:

"The theory is, that when these germs escape from their natural habitat in the intestine their environment becomes unfavorable and hence they tend to die off. Professor Sedgwick, of the Boston Institute of Technology, thus states the matter: 'Once they begin to travel through soil-pipes and sewers, their food becomes scarcer and less available, and when finally they mingle with the waters of the lake, which are relatively pure and destitute of organic matters, their pabulum must be distinctly scanty. At the same time, in sewage and in the lake, they are subject to the influence of gravity which tends to draw them down into the deeper, quieter layers and finally into the mud at the bottom, while predatory infusoria running through the water may devour them altogether. Lastly, if they tend to float or linger on the surface, they may there suffer from the germinicidal action of the rays of light and perish.' In addition to what is here stated, several of the witnesses are of opinion that the longer they remain out of the intestine the weaker and less virulent they become, and therefore the less likely to cause disease.

"Now it is on this theory that still water is seen to be a better purifier than running water, but in order that still water may, so to speak, do its work, it must have time. A running mountain-stream may carry the germ and be the vehicle of disease 50 miles below the point at which it was discharged into the water."

Then the Chancellor discusses the actual effect of storage

in the reservoir. It is conceded by everybody that if the germs remained in the reservoir for the time which is represented by its full storage capacity, the water would probably be in safe condition, but it was shown that when the reservoir was drawn down and when there was a heavy rain on the watershed, the purifying capacity was much less than that calculated. Some of the experts attempted to maintain the position that the water would necessarily pursue a roundabout course, following down one side of the reservoir to the further end and then back again. It was pretty well settled by the floats, however, that in times of sudden rain, water found its way quickly across the end of the reservoir. In this connection, the Chancellor says:

"This much would seem to be certain: That the current, such as it is, on the principle that the water goes along the line of least resistance, necessarily tends to flow from the mouth of the river towards the gate-house and spillway. If more water is flowing over the spillway than through the gate-house, then the current would be more pronounced in that direction. If the wind is blowing hard from the northwest, this tendency would be augmented. The larger the volume of water flowing in the river the stronger the current. It nowhere appears in the testimony how far down these currents would extend, so far as they are set in motion by the passage of the water toward the spillway. It is at least probable that the friction of the upper currents upon the lower, created either by a considerable wind or by a freshet, would tend to set the lower currents in motion in the same direction, in accordance with the result of Mr. Kuichling's observations in Lake Michigan, and that these currents would be directed toward the gate-house rather than toward the Parsippany dam.

"There is a fact in this connection which seems to me to be very strong indeed. I called attention to its significance on the argument, and counsel for the water company could not, so far as I could see, explain it away. In the freshet of 1893 and during 108 consecutive hours, or nearly four and a half days, there was discharged at Boonton 9,885 million gallons. The reservoir contains, above the lowest effluent pipe, 7,300 million gallons. What would have become of the water in the reservoir had it then been full? It is absurd to suppose that this immense volume of water would have flowed over the top of the water already there and left it undisturbed. It would undoubtedly have mingled with it and very largely displaced it. There can be no question that in two or three days some of the inflowing water would have reached Jersey City. It will, no doubt, be said that this was an exceptional flow, but the fact is that a very similar freshet occurred only a year or two before.

"I will take, however, what was admittedly a normal year, in fact, a year of very moderate and very even flow. The flow of 1906 is illustrated by Mr. Cook on a diagram. It appears therefrom that on March 4th and 5th it was about 900 million gallons per day; on March 6th, 600 millions, and on March 7th, 400 millions. In other words, nearly 2,800 millions of gallons flowed into the reservoir during those four days. This was considerably more than one-third the contents of the reservoir above the lowest point of discharge. Now considering with what velocity the freshet must have entered the stream and how the contour of the bottom must have given direction to its currents, how the friction of the upper strata would have acted upon the lower, is it conceivable that a considerable portion of the river water would not have found its way to the gate-house within a very few days? The freshet occurred in the early part of March. If coincident with a thaw, then the water would have contained the animal matters which had accumulated on the surface during the freezing weather."

That is, under just the conditions which have been found to be most dangerous in general to surface waters, conditions of low storage with a rapid run-off, passing quickly across the reservoir—just the condition that occurred at Plymouth, Pennsylvania, in 1885, and at New Haven more recently—there was a strong probability that the purifying action of the reservoir would break down. Analytical data showed that such was the case. The total number of bacteria is ordinarily fairly low in water collected at the outlet of the reservoir, but the results are notably variable. According to Dr. McLaughlin's examinations made for the Water Company monthly during a period of three years, 5,400 bacteria were found on one occasion; three other samples showed counts over 1,000, and eight others gave numbers between 500 and 1,000. At Jersey City, after passing through the 22-mile conduit, the bacterial condition of the water is of course better, but the same sort of irregularities are manifest. Mr. G. C. Whipple (for the city) found numbers varying between 120 and 2,500 in 1904 and between 210 and 2,400 in 1905; Dr. McLaughlin's results were not very different; and all along, as the Chancellor showed in his review of the evidence, high counts and the presence of colon bacilli were associated with rains on the watershed and sudden rise of water in the reservoir. Melting snow produced high water on December 22, 1906, and on December 26, 1906. I found 2,200 bacteria per cubic centimeter at Jersey City; in the afternoon of the same day, and on the 27th, the numbers fell to normal values of 150 and 200. The reservoir rose again rapidly on March 13th and 14th, 1907. On March 19th I found counts between 600 and 1,200 at Jersey City, and *B. coli* present in one-tenth of a cubic centimeter.

August, 1910

In order to meet these facts the experts of the company fell back on average analyses, and on this basis made out a fairly good case. Taking all samples throughout the year, colon bacilli were present only 7% or 8% of the time, and the average efficiency of storage compared not unfavorably with that of many water filters. The experts for the city maintained, however, that conclusions based on the proportion of samples showing *B. coli* rested on the assumption of unchanging conditions, and did not apply to a varying purifying mechanism like a reservoir. In the Chancellor's words:

"If 50 samples were taken from the same place on the same day and it were found that *B. coli* were not present in one cubic centimeter in more than 50% of the samples, then the water would be considered good; but if one sample were taken on one day in each week of the year and it were found that on 45 days *B. coli* were not present and on 7 days they were, all that that would indicate would be that on 45 days the water was good and on 7 days it was either bad or, at least, open to suspicion. We certainly would not be justified in concluding that it was unobjectionable during 7 weeks (if a day is to stand for a week), only because it was good for 45 weeks; if, in point of fact, it were found that for those 7 weeks it was bad."

From this point of view, and judging the character of the water by the colon tests made by the company's own experts, the Chancellor concluded that:

"The water was of doubtful quality in 1904, 7% of the time; in 1905, 5% of the time, and 1906, 8%. This, in days, would be, in 1904, 25½ days, in 1905, 18 days, and in 1906, 29 days, or, if we include Prof. Winslow's analysis 31 days."

This careful study of the efficiency of a reservoir in self-purification led, as I have stated, to the conclusion that generally the reservoir worked excellently. At times, if the conditions of water in the reservoir, the stream-flow, wind, etc., were right, the purifying mechanism (generally efficient) broke down and large numbers of bacteria were carried across the intake. It was even claimed by the experts on the city side that on one occasion there was a slight increase in typhoid fever in Jersey City following one of these lapses. The evidence was not conclusive on that point, and the general death-rate from typhoid fever was exceedingly low; in fact, Jersey City has one of the lowest death-rates from typhoid fever in this country. Nevertheless, the evidence was sufficiently clear to convince the Chancellor that there was danger on those few days in the year when conditions were just right to make the reservoir an imperfect purifying-mechanism. Of course, the question whether typhoid fever did or did not follow those breaks had no important bearing on the practical proposition. It might easily be that for a number of years there

would not be typhoid bacilli in the Rockaway River at just the right time to be carried across. Nevertheless, if the pollution existed, there was always the chance that at some time the specific infection would be present. As the Chancellor stated the case:

"I am, on the whole, obliged to conclude that all the evidence favors the theory that water, under certain combinations of circumstances occurring perhaps on an average two or three times a year, will pass from the mouth of the river to the Jersey City reservoirs in two or three days. Every fact is favorable to this view and no fact, so far as I can discover, is opposed to it."

The Court therefore reached the opinion that "Patrick H. Flynn and the Jersey City Water Supply Company have not complied with those provisions of the said contract which stipulated that the supply of water delivered to Jersey City shall at all times be free from pollution, it appearing that the works, as a mechanism for the purification of the supply, are not at all times adequate and reliable."

It was therefore decreed that "There shall also be deducted from the contract price the cost of establishing intercepting-sewers and drains and sewage-disposal works, capable of substantially preventing the contamination of the Rockaway River above the Boonton Reservoir from the sewage of the City of Dover, the City of Boonton, and the Village of Hibernia, which cost shall be hereafter determined by the Court."

It was also provided that the company might "in lieu of and as a substitute for all or any of the sewers and sewage-disposal works . . . present other plans or devices for maintaining the purity of the water delivered by the company to the city throughout the year." Evidence in regard to these plans or devices and their cost, and in regard to the cost of the sewers and sewage-disposal works, was to be presented before a special Master,—the Honorable William J. Magie. This constitutes the second branch of the case, on which the evidence is now all in, but on which a decision has not yet been rendered. The experts for the city have proposed sewage-disposal works of several types. The sewerage plan, which was at last practically agreed upon by experts for both sides, was for a trunk-sewer running down the Rockaway River from Dover to a purification-plant below the Boonton dam. I believe the plan of the company's experts provided for a trunk-sewer on one side and the city's experts on the other, but there was very little difference in either the designs or the estimates. The collecting systems differed in extent, but the revised plans of Mr. Nicholas S. Hill, the principal engineering witness for the city, were only \$544,540, against estimates of \$376,005 by Mr. Rudolph Hering, and \$420,595 by Mr. G. W. Fuller, for the company. For Hibernia, where there is no water-supply available, Mr. Hill proposed a pail-system of collecting

and disposing of excreta at an estimated cost of \$23,475. Furthermore, the city maintained that the capitalized cost of operation and due allowance for depreciation should also be included, bringing the total deduction up to \$872,744.

The company's alternative plan, which was, of course, much cheaper than any sewerage system, was a chlorine-disinfecting plant for treating the water as it was taken out of the reservoir. This plant—which was made possible, I think, by the experiments carried out at "Bubbly Creek" at the Chicago Stock Yards—is described in the *Engineering News* for June 24, 1909. As all its details may not be familiar to the society, I will refer briefly to some of them.

The plant as used at Boonton contemplated no filtration of the water but simply treatment either with chloride of lime, or with hypochlorite of sodium produced by the electrolytic treatment of salt. In either case the action is a simple disinfection.

I should not, perhaps, say that the action is simple, however, because a great many pages of testimony were wasted on the discussion as to whether it was the chlorine that killed the bacteria or whether the chlorine liberated oxygen that killed the bacteria. At any rate, there is no doubt that when hypochlorites are added to water or sewage containing bacteria, a large proportion of the bacteria are killed. The plant involved tanks in which the bleaching powder was dissolved, orifice tanks to which the solution was pumped and from which it was wasted over a waste-weir continually, and a grid through which the solution of bleaching-powder was discharged into the stream of water coming from the reservoir at a number of points, insuring a fairly perfect mixture. The amount of bleaching-powder added at first was 36 pounds per million gallons, equivalent to 1.4 parts per million of available chlorine, and about 4.2 parts per million of bleaching-powder. Gradually the amount was cut down to 5 pounds per million gallons, corresponding to 0.2 of a part per million of available chlorine, or 0.6 of a part per million of bleaching-powder,—a very minute dose for this large volume of water. The result was the production of an effluent in general very low in bacteria. According to the experts for the water company, bacterial numbers ranging from 30 to 1,600 were cut down to an average of 15 per cubic centimeter, and during a period of a little less than three months, the colon bacillus was found by the company's experts only once out of 455 tests (*Engineering News*, LXI, 699). Clearly the bleaching-powder exerted a strong bactericidal action. The city contended, however, that the plant did not fulfill the contract and did not supply a pure and wholesome water throughout the year. This contention, which, of course, is not yet an accepted one, being still before the Chancellor,\* was based on several considerations, and in reviewing them I can only be held responsible for my own opinions, as I have not

studied all the other experts' testimony in the case on either side.

In the first place, the city maintained that the disinfection-plant at the Boonton dam could not properly be held to constitute a process, alternative to the construction of sewers and sewage-disposal works on the Rockaway watershed. Sewage-disposal and water-purification are not interchangeable processes; both are essential according to modern standards. It was Mr. Hering, I think, who coined the aphorism, "Nothing put into a stream without purification, nothing taken out of a stream without purification." Sewage-purification should keep out the grosser pollution, but water-purification is still required at the other end to remove the incidental pollution that must get into any surface-water. To quote from Mr. Hill:

"It is not sufficient to boil sewage or treat it chemically and then drink it. Under the special condition of flood following low water and accompanied by westerly wind, with which the present case deals, the water at the dam is not a proper raw water for safe treatment. Jersey City, in order to have a safe supply, must remove gross sewage-pollution and then purify the water at the dam. It is therefore manifestly unjust that the water company should evade the more costly fraction of the necessary burden which it contracted to bear."

Besides this primary contention, that a disinfecting plant could not properly be accepted as "in lieu" of sewage-purification plants, the experts for the city maintained that chlorine disinfection, as practiced at Boonton, did not yield a water "pure and wholesome and free from pollution deleterious for drinking and domestic purposes." For the most part, the water delivered at Jersey City was of excellent quality as judged by the ordinary bacterial tests, but there were still irregularities, which coincided as before with periods of heavy rain on the watershed. For example, near the end of October, 1909, there were severe rains, and on four days following October 26th, several samples of water at Jersey City showed colon bacilli present in 6 or 7 out of 10 one-cubic-centimeter samples. These were only occasional samples, it is true, for others collected on the same days failed to show intestinal organisms; but there were similar findings of intestinal bacteria on January 28, and on March 4, 1909, as shown by the analyses reported by the experts for the city.

On March 4th, the following results were obtained by Dr. Charles E. North:

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\*Hon. W. J. Magie, the Master in the case, has recently rendered an opinion, supporting the contention of the water company in regard to the character of the disinfected water and the propriety of substituting a disinfecting plant for sewage disposal works. The final decision of the case of course rests with the Chancellor.

BACTERIOLOGICAL EXAMINATION OF WATER AT JERSEY CITY,  
MARCH, 4, 1909.

Sample.	Bacteria per c. c.			<i>B. coli.</i>	1 C. C.
	20°	37°	Acid Formers.	Lactose bile.	
1	3600	367	200	+	—
2	620	700	220	0	3
3	1800	520	210	4	0
					6

The experts for the Company also noted the pollution of the water on this occasion. Similar excessive numbers of intestinal bacteria were testified to in August, September, and October, 1909, by Doctors Jackson and North, experts for the city. It seemed to me and to others that these high numbers of bacteria were due to the fact that the sudden increase in organic matter sweeping across the reservoir at times of rain was too much for the normal dose of bleaching-powder, and this possibility apparently constitutes one fundamental defect of the process. When a burden of extra organic matter is put on a slow sand-filter, it works with a higher percentage of efficiency than before, but bleaching-powder is markedly decreased in efficiency by the presence of organic matter; that is, it oxidizes many kinds of organic matter before it oxidizes the bacteria. The amount of bleaching-powder must be adjusted to the organic matter and the bacteria in order to get efficient results. In water where the organic matter varies widely, there is danger, unless a large excess of bleaching-powder is added constantly, that a sudden influx of pollution will make the process inefficient. This is the first serious objection that can be brought against this usually excellent process.

The objections that I am pointing out are, I think, of fundamental importance in connection with the general introduction of this practice of water-disinfection. There is no doubt that the procedure of chlorine treatment, as worked out at the Chicago Stock Yards and at Jersey City, marks a great advance in water-purification. It is perhaps the greatest step that has been taken since the Louisville experiments on mechanical filters, nearly ten years ago. At the same time, with every new process, it is important to know the limits within which it can be safely used. The next few years will doubtless be devoted largely to working out these fundamental facts, to ascertain how far and in what ways this procedure can be trusted. The first possibility of danger seems to me to lie in this irregular action in water of widely fluctuating composition.

A second question arises in connection with the effect of the bleaching-powder upon different forms of bacteria,—a very interesting point. It has been generally assumed that all that was necessary to know in order to judge of the sanitary quality of a water was the count of total bacteria on gelatine and the deter-

mination of colon bacilli, as it was thought that other bacteria, and whatever other detrimental substances might exist in the water, would behave in a manner similar to the total bacteria and the colon bacilli. This belief is justified in the processes of purification dealt with heretofore, with self-purification and with filtration, including under that term not only artificial filtration but also, of course, natural filtration through the soil. All our water supplies are derived ultimately from surface water running off the surface of the ground or running down through the ground. In both the processes of dilution and of filtration all bacteria and most kinds of organic matter are eliminated together in parallel, and therefore it is fair to take a common, easily isolated, type like the colon bacillus and use that as an index of all the rest. Introduce this new idea of disinfection and the old index ceases to be reliable, because the organic substances in the water do not behave in a manner similar to the bacteria and other types of bacteria do not behave like the colon bacillus.

We recognize three types of resistance to such oxidizing action as that of chlorine,—ordinary vegetative cells, cells with a waxy envelope or of waxy substance, like the tubercle bacillus, and spores like anthrax and *B. sporogenes*, which are still more resistant to the action of the disinfectant. There is danger, therefore, that when the colon bacilli are removed these other types may remain. The amount of chlorine used in disinfecting water would almost certainly not affect spore-formers like the anthrax bacillus, which has several times, in recent years, been transmitted in water to cattle, and might just as well be transmitted to man; it seems probable, too, that it would not destroy the tubercle bacillus which gets into water from the sewage of man and from the excreta of cattle, and which recent investigations have shown to be, to an appreciable extent, a water-born disease.

In the third place, the possibility has appeared in the last few years that water-supply may cause disease in other ways than by transmission of living specific germs. The fact that typhoid fever is by no means the only disease caused by polluted water was shown first in this country by Mr. Hiram Mills, of the Massachusetts State Board of Health, and was enunciated in clear and definite form at the Engineering Congress in 1904 by Mr. Allen Hazen, having since become known as the Hazen theorem. The Hazen theorem is that for every life saved from typhoid fever by purification of water, two or three lives are saved from other causes. This fact has been established, I think. When pure water is introduced, there is a fall in the general death rate much larger than can be accounted for by the fall in the typhoid death-rate. Professor Sedgwick has called attention to the fact that among the specific diseases affected in this way are tuberculosis, pneumonia, bronchitis, and infant mortality. Just how these diseases are affected we do not know. Whether the germ is car-

ried in the water—as seems probable in the cases of tuberculosis or whether there are other substances in the water that have a lowering effect on the vital resistance—which seems perhaps a more probable assumption in the cases of pneumonia and bronchitis—we do not know. But the fact that other diseases than typhoid fever are caused by polluted water makes uncertain the value of a process which simply kills certain kinds of bacteria and does not remove other deleterious substances.

This case will, I think, take its place as one of the historical law-suits in connection with the subject of water-supply, and in closing I will call attention only to what seem to be the two main results.

First, the case led to a full and thorough discussion of the philosophy of self-purification. Of course, the Chicago-St. Louis case was the first great demonstration of the extent of self-purification of streams, and showed that it is an enormous force; also that it is possible to discharge the sewage of a city like Chicago into the water-supply of a city like St. Louis, under the proper conditions of dilution and self-purification, without any increase in death-rate great enough to be demonstrated to the satisfaction of the Supreme Court. In the Jersey City case the shortcomings of purification by dilution were strikingly brought out, and I think that is a very important point in connection with this whole subject. Self-purification, while it is a very real method of water-purification, is yet an unreliable method; conditions in a reservoir or lake are constantly varying, and a purifying-mechanism of this kind that may be ample and efficient for 350 days of the year may fail on the other 15 days—a lesson of caution in the use of this process of self-purification. It is a valuable process, but unless the self-purification is considerable, unless the storage period exceeds two weeks or more at all times, and under all conditions of weather and flow, then the system is not one which is absolutely reliable, and requires another safeguard.

The second branch of the case succeeded in demonstrating the great value of the process of the bleaching-powder treatment, and it is said that today this process is in use in about one hundred plants in the United States. It was shown conclusively, in connection with ordinary water-bacteria and the colon bacilli,—the principal signs of danger in supplies of fairly good quality to start with,—that bleaching-powder would secure excellent purification for almost all the time at a cost so light as to be practically nominal. The estimate made by the experts for the company was perhaps well within the range of probability, but they figured that it would cost them only 14c. a million gallons, which is extremely low. Chlorine is now used, as you are aware, in many cities in conjunction with filters,—at Poughkeepsie, N. Y., and at Indianapolis, in connection with slow sand-filters; and at Little Falls, N. J., Harrisburg, Pa., and a great many other

plants, in connection with mechanical filters, where the bleaching-powder process not only introduces an added safety to the water but also cuts down considerably the cost of operation. With chlorine, we need simply add enough alum to get rid of the clay, and where there is little clay and a great many bacteria the amount of alum can be considerably reduced. Chlorine has been used at Corning, N. Y., and Ridgewood, N. J., for purifying well-supplies, and it has been used with great success—as at Minneapolis and Montreal—for treating river-waters. This process marks a great advance in our water-works practice, but it is important that, like other new things, it should not be misused. The practical difficulties having been overcome, the engineers and chemists who have worked with this process are likely to think it will do anything. I do not believe that the bleaching-powder process will work miracles, and that it will be possible, by its use, to turn sewage into drinking-water, but I do believe that it adds a third to our two recognized methods of water-purification, storage, and filtration. My own view of the matter is that with the increasing recognition of the importance of pure water, and of the growing opinion that water causes disease in various ways, at least two of these three safeguards ought to be used; that treating a stored water, a lake water, or a reservoir water—any well stored water—by chlorine or by filtration, will furnish a satisfactory supply, and that for a river-water supply which has not been stored, both filtration and bleaching-powder will give the best results. Of course, just how far it is necessary to go in these respects will be shown by practical tests carried on in the next few years. At any rate, it is important that this new process should have as a net result the improvement of the character of our water-supplies; it ought to enable cities with poor water-supplies to get fairly good ones, and cities which have fairly good water-supplies to get excellent ones, but it ought not to be made a means for lowering sanitary standards by substituting partially purified supplies for those that are well purified.

#### DISCUSSION.

*Mr. A. Bement*, M. W. S. E., chairman: We are fortunate in having had presented to us a matter of such vital interest, and I am not sure but what it should bring to us a lesson here in Chicago. We have been disposed to consider, in the past, that we had a very good water-supply and that it could be used without question, but ideas have changed and I think it would be well to take into account the facts that have been presented, when considering our own situation.

*Prof. A. N. Talbot*, M. W. S. E.: The presentation of this interesting subject brings to mind to all of us, I think, in a new way the great importance of this method which has been developed within the last few years. It is quite possible that the

use of bleaching-powder may some day be of advantage to Chicago in treating its water-supply, making the second of two methods which Professor Winslow has stated should be used, an additional safeguard to the storage obtained in the great lake. It seems to me that the Society is fortunate in having the matter presented, so ably and so completely, by Professor Winslow.

*Mr. B. J. Ashley, M. W. S. E.:* I am deeply interested in the subject of water-purification. An instance of water-pollution came to my notice this week, which I will mention. In a letter from Rochester, N. Y., information was revealed that several neighbors outside of the sewer district had been advised by the local plumbers and, I think, by an architect, that to dispose of the sewage from their houses they could dig large cesspools about 12 feet square and 12 feet deep, with a dividing-wall of brick, laid up without mortar, running through them; and that by drilling a hole some 30 or 40 feet into the ground below the cesspools they could tap them and run the surplus liquid off into an underground vein of water known to be passing below. I regret to say that one of the men who tried to take advantage of that kind of sewage-disposal was an ex-brigadier general. So far as civic conscience is concerned, such an act is little short of criminal. While no doubt they obtained their supply from the city water-main, yet wherever that underground vein penetrated and carried the underground current, the possibility of its affording water-supply for neighboring wells is very manifest, and how many wells may be taking water from this vein, even at some distance away, is not known. I could not refrain from writing to the Secretary of the State Board of Health of New York, stating the case to him, but I did not inform him where this instance was occurring.

In the matter of pollution of streams by sewage, I recall a former statement by Professor Winslow, and I wish to ask him to what degree of dilution are the recognized requirements? I think I recall his saying that a dilution of thirty to fifty parts of water to one part of sewage, or of effluent, was considered satisfactory and would prevent a nuisance.

I am glad to note that throughout the country there is a decided advance in the matter of sanitary conscience. People are beginning to learn—and the death-rate is lessening because they are learning—as we all know, and one reason is because of the attention that is being paid to water-supplies and to sewage-disposal.

*Mr. C. D. Hill, M. W. S. E.:* The protection of drinking water is somewhat out of my line, but this particular topic was discussed in my presence last summer by Mr. Alvord soon after the experiments were made at Boonton, N. J., and at that time Mr. Alvord suggested that possibly the hypochlorite process could be used for the drinking-water here in Chicago. Some one made the suggestion that it might be applied at the cribs,

and the counter suggestion was made that it would be quite practicable to apply the process at the pumping stations. When the pumps are discharging a constant quantity of water—a measured quantity of water—an exact proportionate amount of the disinfectant could be used, and it would be a comparatively simple matter to arrange the mechanism. The suggestion was made that while perhaps the process would be unnecessary at present, if analyses at any time indicated pollution of the water at the cribs it could be put into operation temporarily for use as long as it might be needed.

I infer from Professor Winslow's remarks that he does not approve of converting the sewage of "Bubbly Creek" into drinking-water, but perhaps he would not want to be quoted on that proposition specifically.

*Dr. Frederick O. Tonney:* Several suggestions have been made this evening which I think are pertinent to the situation in Chicago. The one made by the last speaker occurred to me some time ago and I think it is a valuable suggestion. I think it is quite well established that the city of Chicago has an excellent water-supply, as water-supplies go, but there are some things in connection therewith that are still somewhat unsatisfactory. The cribs supplying the main downtown district, and in fact those supplying most of the districts of the city are showing very good results, as indicated by the analysis in the city laboratory, but according to these analyses there are two stations which will bear watching. One is the Rogers Park pumping-station, the intake of which is located within a short distance from shore. A filtration-plant has been recently installed in that station, but up to the present time the water still shows a rather high colon bacillus content. The typhoid rate in that vicinity has also been higher than in other portions of the city. The other station I had in mind is that supplied by the Sixty-eighth Street or Hyde Park crib. This is the only crib which is located within what may be considered dangerous distance of a sewer outlet. The Seventy-ninth Street sewer is still discharging into the lake within a distance of perhaps two miles, and in addition it is probable that at times the sewage of the Calumet River is carried as far north as the intake. As is to be expected, the bacterial tests show evidence of occasional pollution, although this is of rare occurrence. It seems to me that in these two stations quite satisfactory results might be obtained by the addition of a germicide applied as a temporary measure until the polluting agencies mentioned could be remedied. I think that the hypochlorite treatment offers, as suggested, a valuable remedy in such cases, and it no doubt represents a valuable addition to the accepted methods of water-purification.

Another point which I have in mind, now of interest to the city of Chicago, is bearing upon the germicidal-treatment of water, in connection with the "Bubbly Creek" suit. While, of

course, the matter is still in the courts and it is, therefore, hardly proper to draw conclusions from the evidence thus far introduced, yet it occurs to me that this case affords an apt illustration of the danger (a natural tendency as a result of over-enthusiasm) of going too far,—of assuming that the process will do more than the facts warrant. No doubt the hypochlorite-process is valuable for the treatment of somewhat polluted waters,—waters which can still be recommended as proper sources for drinking purposes,—but it seems to me that it is going a step too far to try to convert a fresh sewage directly into a potable water by any process as yet developed on a practical scale. Of course the matter will be fought out in the courts and the best evidence on both sides will be presented. At the time of the decision we shall be in a better position to discuss the points at issue.

The subject presented by Dr. Winslow is a matter of vital interest to us all. Personally my attitude is from the standpoint of a hygienist and physician, and as I am not an engineer, many of the practical phases of the problem are perhaps not as clear to me as they are to some of the members of the society.

*Mr. Cement:* Concerning our water-supply from Lake Michigan, on a great many mornings, I have observed water in the bath-tub which has come out of the cold-water faucet which was so dark that I could not see the bottom of the tub, and sometimes it has been black. That condition seems to occur after we have had a north or northeast wind, and I have supposed that the trouble was due, in a measure, to the dumping of dredgings in the lake.

*Mr. Langdon Pearse:* There are several points I would like to speak on. I was connected with the Jersey City work on the city side at the time the suit started and made the sanitary survey of the watershed there under the direction of Mr. George C. Whipple, so I might say I am familiar with every inch of the ground in connection with the case, although I have not been connected with the work since 1904. There is not a sewer on the watershed. As Prof. Winslow showed, there are several towns on the watershed—Dover, with a population of about 6,000; Rockaway, about 1,600, and Boonton, about 3,900.

Hibernia was really the worst place—an iron mine employing about 800 men daily in the workings, and all of their excreted matter was pumped out in the mine drainage into a creek running down into the Rockaway River. At the time, we regarded Hibernia as the place requiring the most immediate attention, but we had not developed any scheme to fix it then. It will probably interest the members here who do not come in contact with such things to explain that, in our sanitary survey, we took the census of every house on the watershed which could in any way drain into the water supply, and listed the provision of sewage. In most cases this meant an inspection of the privy and barnyard. These were all mapped and submitted

as part of the evidence. Most of the pollution was scattered. Some of it, of course, came in direct from privy vaults that dumped into the stream and from water closets discharging into it. The latter were mostly concealed, but we found that the water company's inspector had been in collusion with the people he was supposed to stop, and that many things had gone on unknown to the water company, although they were doing their best to prevent pollution.

The question of the pollution of the reservoir at Boonton was interesting, and I am glad to hear what Prof. Winslow had to say on it. We thought at the time, that is, before the float measurements were made, that it was highly probable in time of storm that the pollution from the surface wash as it came down the river might be swept right across the reservoir directly into the city supply. We felt that the water really ought to be filtered, although the turbidity was not very high. At that time disinfection had not been developed for the protection of such a water supply. The question of storage is important, but it would not protect in a case like this.

The question of the cost of treating the water by the use of bleaching powder brings up a question which I would like to ask, "Is the cost of 14 cents computed for the making of the hypochlorites by the electrolytic process with the electric power free, or is it for the use of bleaching powder?" The Boonton reservoir has a massive concrete dam, rock-faced, with an available fall, I think, of over 65 feet. That power usually goes to waste but could be utilized to generate electricity to transform salt into hypochlorite of sodium. If that is being done, the cost at Jersey City would not be comparable to what we would have here, for instance, to treat the Sixty-ninth Street crib, although I suppose the Sanitary District would be glad to sell its power at a cheap rate to make sodium hypochlorite for the sterilization of Chicago's water supply.

In connection with the water-supply of Chicago and the towns on the north shore, Dr. Tonney, Prof. Bartow, and myself have carried on a series of experiments as far north as Waukegan and have studied this question of turbidity which your Vice-President, Mr. Bement, speaks of, and we find it is not so much the distance from shore that is the element involved, but the question of the depth at which waves will affect the bottom. We find beyond forty feet depth that there is not much wave action, although at the time of heavy storms a slight action may be noticed. In thirty feet of water it is more pronounced, and in twenty feet almost every wind stirs up the bottom. This is probably the condition around the Chicago cribs because they are in shallow water, none of them in more than thirty feet, if I remember correctly. There has also been more or less dredge dumping around them in the past and spoil deposited from the water tunnels themselves, which is being stirred up by every

wind. In that connection I believe the pollution from the Calumet undoubtedly affects the Sixty-ninth Street cribs at times, and I believe always will do so until the Sanitary Canal from the Calumet to the Sag reverses the flow of the Calumet River.

The question of pollution that Mr. Ashley asked in the case of this Boonton reservoir would not apply on account of the actual lack of sewage facilities on the watershed. It is rather curious that such communities should have grown up for so many years without any sewers, but they did, and still flourish.

In figuring dilution, for instance, as in the case of the Chicago Drainage Canal, which has a dilution much less than the relation of one to fifty, that Mr. Ashley asked about, we stated that there was a dilution of three and three-tenths cubic feet per second for every one thousand inhabitants. If this be figured on a per capita water consumption of two hundred gallons per capita, the dilution is about one to eleven. The statement per capita is more comprehensive than the ratio of dilution in gallons on account of the wide difference in the consumption of water and flow of sewage in different communities. At the Thirty-ninth Street Testing Station we find that the per capita flow varies from two hundred to three hundred gallons per capita daily, with a water consumption in Chicago of about two hundred gallons per capita. At Columbus, Ohio, the consumption of water was about one hundred and twenty gallons per capita, and in Massachusetts some towns run as low as sixty gallons per capita and a few even lower, so we try to express such figures for sewage work, particularly dilution, in cubic feet per second per 1,000 inhabitants. The dilution in the Chicago drainage canal of three and three-tenths cubic feet per second per one thousand inhabitants gives a result that is not a nuisance. It would not be safe to drink it at Lockport, and probably not at Peoria on account of the time limit for self purification.

*Mr. Bement:* I think there is no question in the mind of any of us here this evening, or any of the citizens of Chicago who have given thought to the matter, but that it is desirable to have the Sag cut-off to carry away the sewage from the Calumet district. I hope it will not be long until it is begun and that we shall have the water flowing through there as soon as possible.

*Mr. Charles B. Burdick, M. W. S. E.:* There is no question but that the subject which Professor Winslow has presented is of great importance. It should be noted, and I believe that Professor Winslow has emphasized this point, that hypochlorite is not a panacea. A good water must be not only healthful, but pleasing to sight, taste, and smell, and no water is acceptable for the use of human beings that does not possess these requisites. Hypochlorite will not clean a dirty water, although it will practically kill the germ life therein, and therefore, except in case of emergency, its usefulness is confined to clear waters. There are, however, many situations where its use will make a perfectly acceptable water.

The opinion has been quite well grounded among sanitarians that a surface-water should be filtered before it is used for domestic purposes, and the term *surface-waters* includes many waters—particularly from lakes—that are acceptable in every other respect than their germ content. Such waters as these can be rendered entirely acceptable by a treatment with hypochlorite.

There is a further field for the use of hypochlorite in the treatment of shallow-well waters. There are many cases where wells for municipal supplies have been sunk in such situations that the sanitary character of the water cannot be endorsed. There are other situations where the environment of the shallow wells may have been originally good, but where municipal growth has changed the original conditions. Such situations are no doubt legitimate fields for the use of hypochlorite.

Apparently this disinfectant has a further usefulness in the treatment of a filtered water. Our best filtration-plants at times leave considerable to be desired in the sanitary character of effluents, and hypochlorite has evidently been applied as an adjunct to filtration with excellent success. Used in connection with mechanical-filtration, it seems to permit a reduction in the quantity of coagulants used. There appears to be situations, especially in the case of waters of low turbidity, where hypochlorite can be applied in conjunction with the coagulants, and improved sanitary results secured, with a net decreased cost in the purification process. One of the most striking uses of hypochlorite has been its use as a temporary means of correcting quickly a contaminated water-supply. There is no other germicidal remedy that can be so quickly, easily, and cheaply applied.

The paper has been useful in pointing out some of the objections to the use of hypochlorite. Any process that promises so much should be carefully examined, because frequently misuse gives a process a bad reputation. It is quite possible to so overdose a water as to create a medicinal odor, which is a serious objection. I have heard of a case where about  $\frac{1}{4}$  of a grain per gallon produced a perceptible odor, and there are probably many waters which will not stand anything like the amount of hypochlorite that has been successfully used upon the water of the Boonton reservoir.

I am sure it would add to the paper if Professor Winslow would enlarge somewhat upon the effect of overdosing on the general acceptability of the water, and its effect upon the human system.

#### CLOSURE.

*Professor Winslow:* In regard to the cost of treating water by bleaching-powder, mentioned by Mr. Pearse, the cost of 14 cents included the price of bleaching-powder. The free power was used in the plant for mixing and other things. Hypochlorite made from salt is now being used, making the cost still less.

One reason why the towns mentioned have not built sewers is because they are waiting for Jersey City or the water company to do it for them. That is one of the unfortunate results of the whole legal complication.

Mr. Ashley asked about the degree of dilution of sewage which might be given as a recognized requirement. The proportion is one to fifty parts of sewage, but this standard of one in fifty was simply a limit beyond which nuisance would not occur, so that a stream would not become a cesspool; it was not, of course, a question of a potable supply.

Referring to the point raised by Mr. Burdick, I do not think there is evidence that would lead one to believe that the slight amount of chlorine left in the water after treatment under ordinary conditions would be sufficient to have any effect on health. But where the amount is considerably in excess of that necessary to do the work, there may be what is called a chemical or medicinal taste or odor, which is really the odor of the chlorine. That happened, I think, recently at Quincy, Illinois, and is particularly liable to occur when the attempt is made (as it was there) to add chemicals to the water in small quantities with rather crude dosing devices; under such conditions larger amounts get in at one time than at other times. Another thing that sometimes causes an odor is the decomposition of organic matter. When chlorine is first applied it often kills the fungi in the water-pipes and as they die and decay they give an odor to the water.

There were two points I was especially glad to have brought out. One of the speakers intimated that my position would imply disapproval of the "Bubbly Creek" project. That is a point which I have been striving to impress on the lawyer for the Stock Yards company all day. He has been asking me questions about it for four hours and I do not know whether I have conveyed the idea to him or not. I am glad, however, to have conveyed it to this meeting.

The other point was in regard to the application of the bleaching-powder process to the Chicago water-supply. One of the things I had strongly in mind when I came to Chicago, and have had ever since, was the hope of getting some people interested in that proposition. This process should undoubtedly be installed at an early date, for it is exactly the thing to make the Chicago water-supply right, in the places where now it is weak. The cost is very small indeed and there is no reason why water from the Rogers Park or Hyde Park cribs should be delivered to Chicago in a doubtful condition a month longer. Where conditions are very bad, as at Montreal, the process has been put in without question. Of course Chicago's supplies are not of that character—they are not grossly, heavily polluted,—but yet they are at times polluted and this condition ought not to exist.

## THE EIGHT-TRACK BASCULE BRIDGE AT CAMPBELL AVENUE, CHICAGO.

Messrs. C. R. Dart and S. T. Smetters, Members W. S. E.

*Presented December 8, 1909.*

The Main Drainage Channel of The Sanitary District of Chicago is crossed by the Pittsburg, Cincinnati, Chicago and St. Louis Railway, the Chicago Terminal Transfer Railroad, and the Chicago Junction Railway at Campbell Avenue, near 31st Street, Chicago. The first named, and most westerly road, has four tracks at this point, and the second, lying next easterly, and the third or most easterly, have two tracks each, making a total of eight tracks crossing the channel. From this is derived the name of the structure,

### THE EIGHT-TRACK BRIDGE.

The Illinois state laws affecting the Sanitary District provide that bridges over the Main Channel may be fixed spans for a certain length of time, but after the expiration of this period of time, all shall be made movable to permit navigation in the channel. When the channel was opened there were thirteen highway and railroad bridges crossing it, twelve of which were of the swinging type, except that the operating machinery had not been installed. An eight-track *swing span* was also originally designed for the eight-track bridge but was unsatisfactory to the railroad companies interested. After advertising for competitive plans, the design submitted by the Scherzer Rolling Lift Bridge Co. was adopted and the construction of the bridge was completed in the year 1900.

The eight-track bridge is really not *one* but actually consists of *four* double-track bridges lying parallel and closely adjacent to each other, each double-track bridge being to all intents and purposes an independent structure excepting that the piers and abutments are continuous under all the bridges. The P. C. C. & St. L. Ry. Co. operates over the two westerly bridges (Spans Nos. 3 and No. 4), the C. T. T. R. R. Co. uses the next easterly bridge (Span No. 2), and the east bridge (Span No. 1) is used by the Chicago Junction Ry. Co. Each company uses *only* its own bridge or bridges and has nothing whatever to do, up to the present time, with the remainder of the structure.

Each double-track bridge, as completed in 1900, consisted of three spans,—a channel-span resting at each end upon a broad pier, and an approach-span, extending from each pier to an abutment,—each connected with the channel-span over the piers by two panels of stringers supported by a steel bent on the pier masonry. This is shown in Fig. 1 from a photograph and before any work for the new bridge was begun.

The approach-spans are each double-track riveted deck-spans

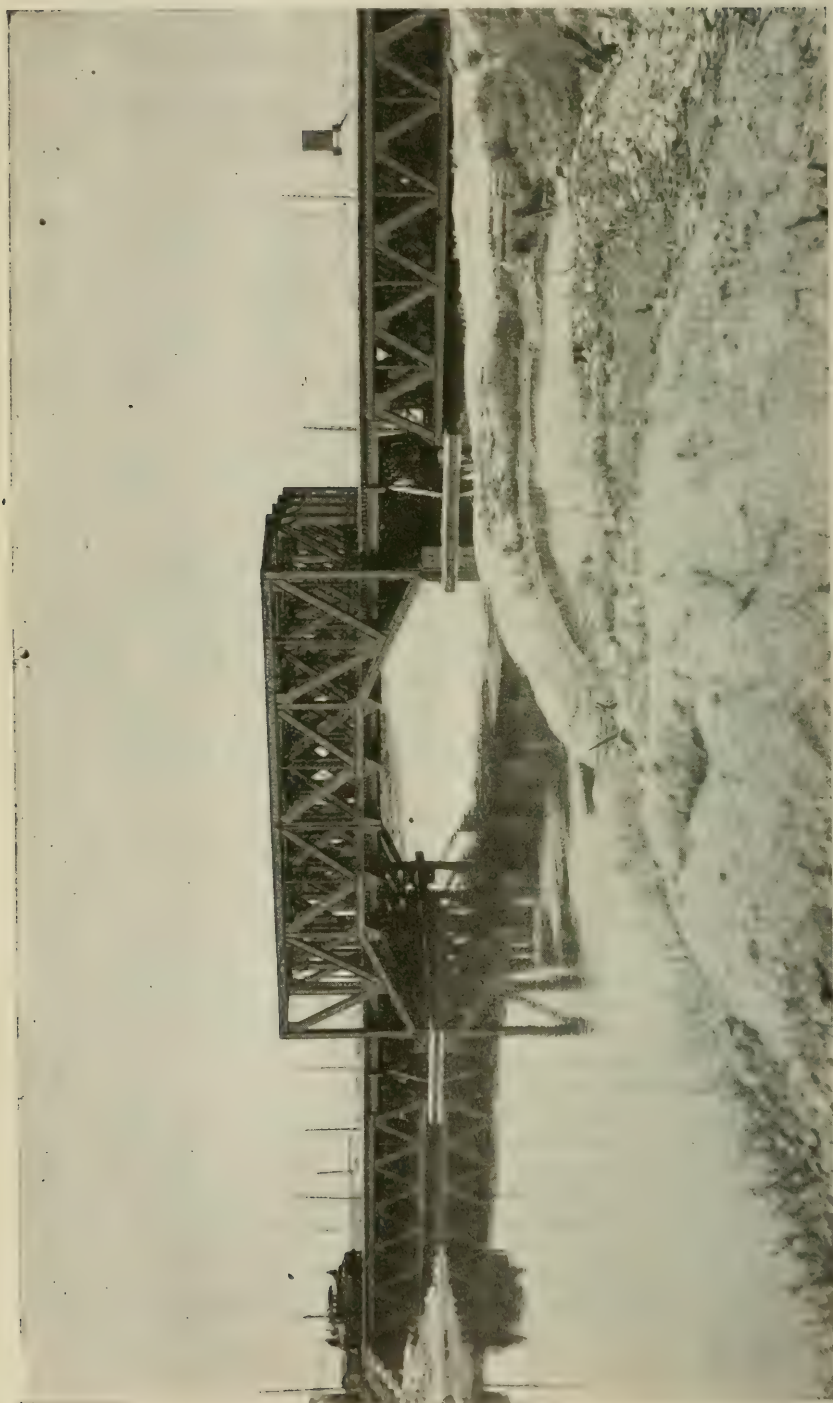


Fig. 1. Old Eight-Track Bridge Across Main Channel.

about 100 ft. in length, centers of end bearings, with the expansion ends on the abutments. The lower chords of these spans are close to the water line.

The channel-span of each bridge was designed to be a double leaf Scherzer Rolling Lift Bridge, but since, under the Sanitary District law, the operation of the bridge was not required for several years, the segmental, or rocker girders, the counterweight, and the track-girders upon which the leaves were to roll, were omitted, as was also all operating machinery. That is, there was constructed only that part of each channel-span *between* the end bearings and *over* the channel, the heel of each leaf or that part over the piers back of the main bearings being omitted. Each channel-span then was a three-hinged arch having one pin at the intersection of the lower chord and end post over each pier, and a pin at the center of the span in the center line of the upper chord. The distance between centers of end pins was 150 ft., each leaf being 75 ft. long.

Connecting the end floor-beam of each leaf with the end floor-beam of each approach-span were two panels of steel stringers supported by a steel bent resting on the center of the pier, as heretofore mentioned. These stringers and bent were intended to be temporary only and to be removed when the leaves were completed by the addition of track-girders, segmental-girders, counterweight, machinery, etc.

In Fig. 2 is shown the original bridges with the track, segmental girders, and operating struts in position as they would have been had they been equipped as movable spans. The illustration shows the general dimensions of channel and approach spans, waterway, clearances, masonry, etc., with the general arrangement of the spans and the railroads operating over each.

The bridge crosses the channel at an angle of  $68^{\circ} 20'$  between center-lines. Since bascule, or rolling lift, double-leaf bridges cannot readily be built on a skew, it was necessary to offset them to conform with the angle of crossing. Each span is therefore set  $12\frac{1}{2}$  ft. south of the preceding span, going westerly, which  $12\frac{1}{2}$  ft. is the departure from a right angle in  $31\frac{1}{2}$  ft.—the distance between centers of spans. Because of the skew of the crossing the right angle width of channel in clear between the piers is but 120 ft., although the leaves are 150 ft. long, centers of end pins.

The original bridge was designed in accordance with the Standard Specifications of the Pennsylvania Lines West of Pittsburgh for 1897, with unit-stresses increased for use of steel. The assumed live load was a uniform moving load of 5,000 lbs. per lineal foot of track with a single load of 50,000 lbs. concentrated at any point on each track. This concentrated load was increased 50% for floor and web member connections. The unit-stresses allowed were 9,000 lbs. in tension and 9,000 lbs., reduced by straight line formula, in compression, both modified by the usual

maximum and minimum formula. Shearing and bearing for shop rivets 5,500 lbs., and 11,000 lbs., field rivets 4,500 lbs., and 9,000 lbs., all modified by the maximum and minimum formula. The cost of the substructure of the bridge was about \$330,000, and of the entire superstructure approximately \$250,000—a total of \$580,000 for construction only, including care of traffic and other miscellaneous expense.

Pursuant to the law requiring the structure to be made movable, the Sanitary District in 1907 prepared plans and specifications for completing the movable leaves, including track-girders and anchorage and equipping the leaves with operating machinery. The anchorage was not necessary for live load on the leaves, as they would still act as three-hinged arches under train loads, but was required to prevent any leaf being pushed forward into the channel when the opposing leaf was not in closed position. The shock from the leaf being stopped by the anchorage was to be taken up by an oil-buffer attached to each anchor. There was to be one anchor near the heel of each truss.

The operating machinery in this design was to be placed on a framework located over the tracks on the approach-span at the rear of each leaf, with a long operating strut-rack connecting with the leaf. The power was to be direct-current electricity. One operator on each side of the channel at diagonally opposite corners of the structure was to operate either the four leaves on his side of the channel or two entire bridges nearest to his house, as might be considered most advisable. The specifications for the electrical equipment were not prepared and this work was to be included in another contract.

When the plans were fully completed an estimate was made of the approximate cost, and it was found that in all probability it would be so great that entirely new single-leaf channel-spans could be built for a comparatively small increase in cost and which would be up-to-date bascule or rolling lift bridges, much simpler in operation, and which would act as simple spans when closed. The double-leaf spans required two sets of machinery, four segmental-girders, four track-girders, four anchorages for each span, and an expensive center-lock in each truss to insure that the leaves would engage properly when closing. With single leaves, the number of segmental-girders, track-girders and sets of machinery could be reduced one-half, and all anchorage and center-locks dispensed with, since the single leaf comes down to a bearing on the far abutment, and, after latching, is ready for train service.

There is no doubt that single leaves are preferable to double leaves for railroad bridges and would be most satisfactory to all parties concerned. The old bridge was already ten years old, would still be ten years old when equipped to operate, and was designed for a loading somewhat less than the modern standard and with higher assumed unit-stresses.

In view of these facts, and that, due to the probable longer life of new single leaves, their ultimate cost would be less than the equipment of the old bridge, it was recommended that a new design be made for single-leaf spans.

This was done, bids were received on both the double-leaf and the single-leaf designs, and the contract was let on the latter plan in September, 1908. The new single-leaf spans of the present structure are illustrated in Fig. 3.

The loading used in the new design was in accordance with the Standard Specifications for the Pennsylvania Lines West of Pittsburgh for 1906, namely, 5,000 lbs. per lineal foot of track and a single concentrated load of 60,000 lbs. on each track, the concentrated load increased 50% for floor-beam and web-member connection. The unit-stresses were 7,000 lbs. for tension, 7,000 lbs. (reduced by the straight line formula) for compression, both modified by the usual maximum and minimum formula. Rivet shear, 75% of the allowable unit-stress in the member, and reduced 20% for field rivets.

The two main piers, upon which the leaves of the old bridge were to roll, were not of sufficient width from front to back to take the longer track-girders of the single leaves, and it became necessary to provide a rear support for one track-girder of each new leaf. Four 9 ft. cylinders were provided for this purpose, two behind each main pier, one for each leaf, to be sunk to solid rock.

In Fig. 7 is shown the method of sinking the cylinders and placing the concrete. The Moran lock and the pig iron for weighting down the cylinders are in position. The pig iron was on the site to be used later in the counterweight for the adjustment of the

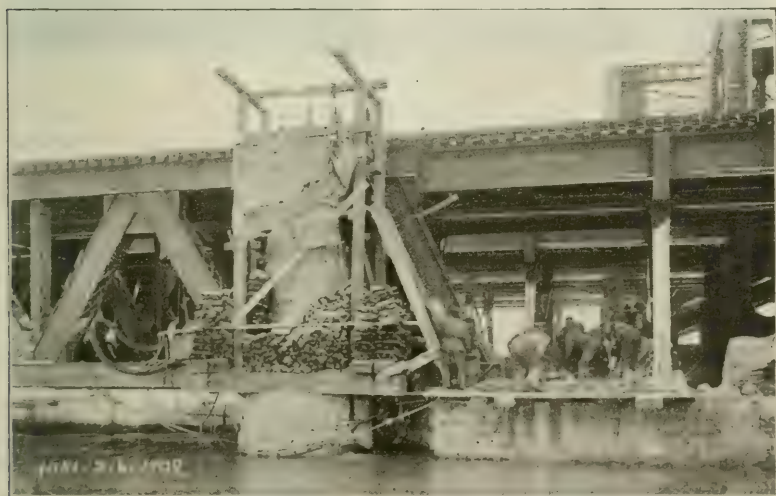


Fig. 7. Sinking Cylindrical Pier—At Rear of Masonry Pier, Bridge No. 4. August, 1910

balance of the bridge. The cylinder shown is at the rear of the old masonry pier of Bridge No. 4. On the left is the front end of an approach span truss. In the right foreground is the main post of the old arch span resting upon its skewback. The segmental and track girders of the old span were not provided and the floor is continuous between approach and channel spans.

The piers themselves, having been built upon solid rock or hard pan, were considered of sufficient strength, since the live load would not be increased by the change and but two new leaves would be placed upon each pier in place of the four leaves of the old bridge. The old spans had been built so close together that it was necessary to place the leaves alternately on the north and on

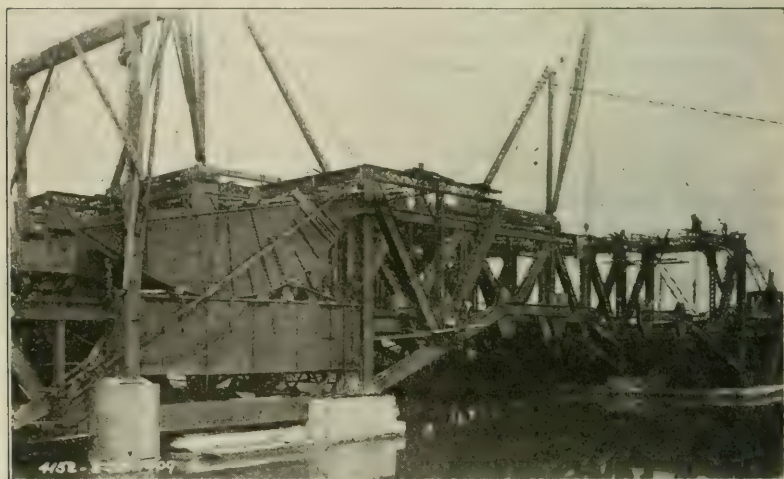


Fig. 8. Taking Down the Old Bridge, No. 1.

the south piers, as there was not room for the operating machinery racks with two adjacent leaves on the same pier.

The forward supports for the new track-girders were located behind the skewback pins of the old arch leaves, which enabled them to be placed without disturbing the old spans or the traffic thereon.

In Fig. No. 8 is shown a view taken during the removal of Bridge No. 1. The old arch span is being taken down as a cantilever. Eyebars and old floor beams anchor the channel span back to the approach spans, as is clearly shown, the eyebars running diagonally across the segmental and track girders for the new bridge which are in place. The rear end of the track girder is carried by the new cylinder pier and the front end is carried just back of the old skewback by a block of concrete which surrounds the old skewback on top of the old masonry. These supports consisted of a plate-girder placed on each side of the old skewback,

supported on I-beam bolsters to provide the necessary bearing areas. Over the pair of plate-girders was placed a large cast steel pedestal upon which the forward end of the track-girder rests. The rear ends of the track-girders rest upon pedestals placed one on the pier and the other on the 9-ft. cylinder. The cylinders were so located that they also could be constructed without interference with any part of the old structure. All pedestals and supports were surrounded with reinforced concrete at the forward bearings, this concrete including the old skewbacks which had been originally thoroughly anchored to the piers by long, heavy rods.

Work in the field was commenced in the late fall of 1908, by sinking the cylinders and placing the track-girder supports on the piers. Each cylinder, which was to be placed in 24 feet of water, consisted of a cylindrical shell of  $\frac{1}{2}$ -in. steel, 9 ft. in diameter, which it was proposed to sink into the mud on the bottom; and, when a seal was obtained, the cylinder was to be pumped out, the excavation continued to rock and the cylinder filled with concrete. The lower part of the channel, however, had been excavated in hard pan and the seal could not be obtained. Compressed air was finally resorted to, using a Moran lock, and the cylinders were sunk to rock and filled to about the water's surface with concrete, without difficulty and without mishaps. The entire substructure work was completed during the winter of 1908 and 1909, considerably before it was needed for erection of the superstructure. Rock was reached at about elevation minus 45 ft. at the cylinders on the south side of the channel, and at about elevation minus 35 ft. on the north side, referred to Chicago city datum.

Up to this time all work had been carried on without interrupting traffic on any of the bridges. In order to erect the superstructure, however, it was necessary to divert traffic from each bridge to be reconstructed to the adjacent span. The necessary track changes were made and traffic diverted from the east bridge (Bridge No. 1) on July 12, 1909. The track-girders might possibly have been placed before traffic was diverted, but this course would have caused interruption of train service, would have resulted in little gain in time and would have necessitated considerable extra cost in handling the girders. After traffic was diverted, therefore, a gallows-frame was erected over the tracks at the forward bearings of the girders, secured to the end-posts of the old leaves, and another frame was placed over the tracks at the rear bearings of the girders. This is shown in Fig. 9. Each girder is a box  $42\frac{1}{2}$  ft. long and nearly 11 ft. deep, weighing 71 tons. With these appliances the girders were both lifted from the cars and placed on the pedestals without any trouble on the day received at the site. The old tracks, old stringers and bent, between the girders, were then removed, and the new floor-beams, stringers, and bracing between them were assembled and riveted up during the following week. The tracks were then relaid and the cars loaded with the

segmented-girders were placed thereon July 23, and these girders unloaded with the gallows-frames used in placing the track-girders. The weight of each segmental-girder was 56 tons.

During the erection of the track-girders and parts between the same, rivets were being cut out in the old channel span; that is, the heads were cut off, leaving most of them in place ready to be backed out and with sufficient bolts inserted for safety. As the channel beneath the bridge must be kept open for navigation, false-work could not be used and it was necessary to remove the old leaves as cantilevers. The floor system was taken out and the top of each end-post of each leaf was anchored back to an old floor-

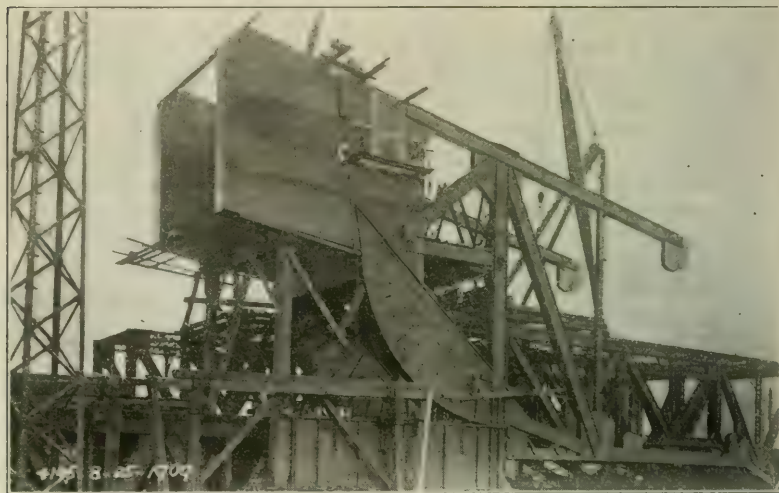


Fig. 9. Placing of Track Girders, Etc.

beam placed in the trusses of the approach-span at the rear of the leaf.

The anchor-chains, made of old eyebars, ended in take-ups in the form of bolts at the anchor floor beam, by means of which bolts the chains were tightened to relieve the load on the center pins of the trusses. This done the removal of the old channel-span trusses was accomplished piece by piece, beginning on each leaf at the center of the span. The removal was performed by derricks located on the adjacent spans, one on each side of the channel. No difficulty was experienced in this work, the removal of the first old span being completed on August 5th. The old leaves being out of the way the segmental-girders were tilted to the position they would have in the leaf in its closed position; or, more precisely, with the forward end of the leaf about 4 in. from the full closed position. (See Fig. 9.) The girders were securely braced, each with a steel inclined post, the upper end of which engaged a tooth-

hole in the perimeter of the segmental-girder and the lower end held by a tooth on the track-girder. Adjustment was provided by a steel wedge between the tooth and base of the post.

The segmental-girders shown in Fig. 4 have two webs, each  $\frac{3}{4}$  in. in thickness. Each web is reinforced around its perimeter with four  $\frac{5}{8}$ -in. and one  $\frac{3}{4}$ -in. side plates, and with a 7 by  $3\frac{1}{2}$  by 13-16 in. curved connection angle, making a total thickness of 4 13-16 in. at the perimeter of each web, or  $9\frac{5}{8}$  in. for both webs. The total load transferred from each girder, 1,738,000 lb., makes a unit load of 180,000 lb. per lineal inch of bearing, or about 540 r, the radius being 27 ft.  $9\frac{1}{2}$  in. This  $9\frac{5}{8}$  in. of surface mentioned, however, bears on a curved sole plate attached rigidly in place by rivets, and which provides the surface that is in contact with and rolls upon the track-girder.

The curved sole plate is  $2\frac{1}{2}$  in. in thickness and acts to distribute the load over a somewhat larger area where it bears on the track girder. The track-plates on the track-girders are planed off to permit a total bearing of but 11 linear inches, giving a unit load of 158,009 lb. per linear inch, or 470 r, the radius of the outside of the curved sole plate being 28 ft. The actual bearing area is several inches in width over the restricted length of 11 inches.

The assembling of the counterweight box was then commenced at the rear upper end of the girder. The counterweight box consists of steel plates stiffened with angles and with interior bracing, and is filled with concrete reinforced with rods for tension. The main portion of the box, extending across the leaf from truss to truss, is as deep as possible longitudinally with the leaf, the depth being such that it will not strike the track on the approach-span when the leaf is raised. To obtain additional weight, blades  $3\frac{1}{2}$  ft. thick are projected back of the main box and pass down each side of the approach-span to near the water level when the leaf is up.

As the box was assembled a strong timber-bent was placed beneath it as an additional precaution during erection of the leaf. At the same time a portion of the trusses over the channel and immediately forward of the segmental-girders were placed as rapidly and as far as was possible without overbalancing that part behind the bearing points of the whole on the track-girders. (See Fig. 9).

The counterweight box having been assembled and riveted (or nearly riveted), erection of the trusses was continued. In Fig. 10 is shown the span when partially erected, with derrick in position on adjacent old span. This derrick did not interfere with the traffic on the old span. Concrete was placed in the counterweight box in sufficient amounts and at such times as was necessary to keep the leaf slightly over-counterweighted at all times, so that there was always a load on the rear supporting-bent under the counterweight box; but for safety the rear end of the leaf was



Fig. 10. Span of New Bridge Partly Erected.

anchored down with cables passed over the tops of the counter-weight blades and fastened to the track-girders.

Work was continued in this manner until the forward end of the leaf was in place over the supporting-bent on the opposite pier. This is shown in Fig. 11; this point was reached on September 9, 1909. The leaf was found to be practically as expected as to alignment and elevation, the variation from the calculated alignment and proper relative elevation of ends of trusses being but a fraction



Fig. 11. Erection of Bridge No. 1, Almost Completed.

of an inch, which was easily corrected. This variation was avoided entirely in the erection of subsequent spans by giving lines and levels as the work was assembled. These were not given in erection of the first leaf.

When the erection and riveting of the leaf was completed the timber-floor and tracks were placed and the leaf was drawn down

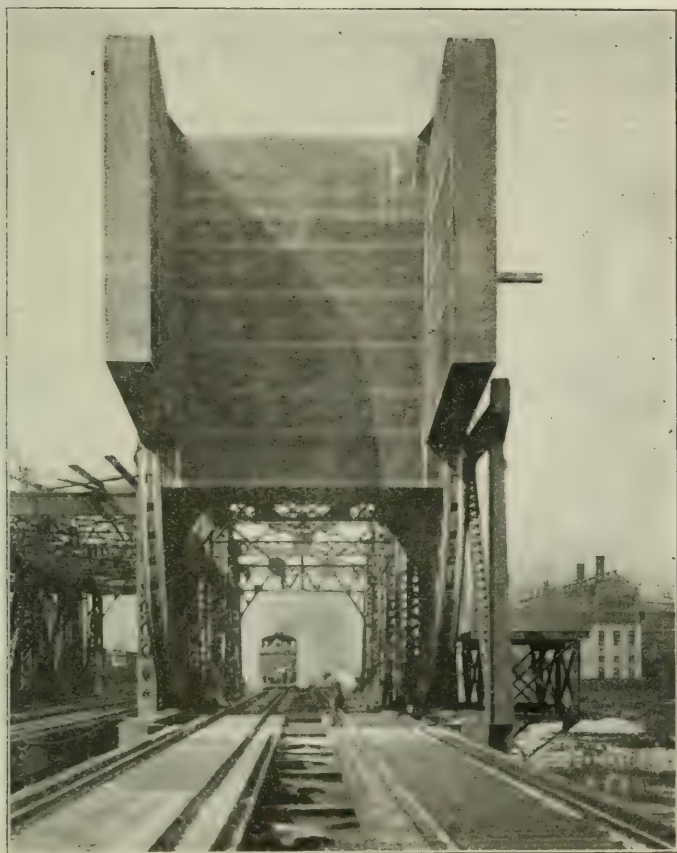


Fig. 12. End View, Bridge No. 1.

on its forward end support and tied there with cables, the final balance to be made later with pig iron placed in pockets in the counterweight box. These pockets are located at top and bottom of the box, so as to provide for adjustment of the balance of the leaf in all positions.

Traffic was returned to Bridge No. 1, after reconstruction as hereinbefore described, on October 2, 1909. The entire length of time the span was out of service was therefore 82 days.

August, 1910

The operating machinery for raising and lowering a leaf is placed upon the leaf itself, supported upon a framework over the tracks just forward of the counterweight box and back of the main post over the forward end of the segmental-girder. A shaft passes through this post in each truss at the center of the circle of which the perimeter of the segmental-girder is an arc. The center line of the shaft, therefore, moves in a horizontal plane as the leaf is operated and remains in that plane for all positions of the leaf. A pinion at the outer end of each shaft engages a horizontal fixed rack placed immediately adjacent to and outside of each truss. Each rack is connected with and supported by the track-girder beneath the same, the length of the rack being slightly greater than the maximum horizontal movement of the shaft when the leaf is operated. The racks between the bridges could not be placed until the adjoining old spans were removed.

Each main operating-shaft just described is geared back to a long shaft extending across the bridge, connecting the two sets of machinery. No equalizer is provided, as it has been found unnecessary in spans of this character, the flexibility of the leaf being sufficient to practically divide the load between the two racks. To the long cross-connecting shaft just mentioned will be geared two 50 H. P. direct-current electrical crane motors each provided with a brake operated by a solenoid. This brake releases automatically when the current is cut into the motors and sets again when the current is cut out. The brakes can be released for coasting by means of a foot switch at the controllers in the operator's house.

An auxiliary brake, released by a small motor, is also placed on the long cross-connecting shaft as an additional safety guard in case the solenoid brakes should fail to act or should be insufficient. This brake must be released by means of a switch in the operator's house before the leaf can be moved, and is set again by opening the switch after the operation.

The cross shaft is also geared to a smaller shaft upon which are two chain wheels provided with chains reaching down to the floor of the bridge. With these chains the leaf can be moved by hand-power in case of failure of the power or of the motors.

At the forward end of the leaf is provided a heavy latch-bar which, when the leaf is closed, can be pushed forward into a casting on the supporting-bent. This latch is operated by a small motor and is also provided with a means for hand-operation. All electric motor circuits are provided with automatic cutouts at limits of the movements of the leaf or of the latch and also with indicators to show position. The latch machinery and operating machinery are interlocked with each other and with the railway interlocking signals. A cutout in the operator's house places the control of all current to the motors in the hands of the signalman in the interlocking tower at the railroad crossing south of the bridge.

The erection of the second span to be reconstructed (the west

span or No. 4), was commenced by diverting traffic therefrom on September 15, 1909. The work was carried on in the same manner as on Span No. 1, excepting that by reason of previous experience the work was laid out and executed to much better advantage and traffic was restored to the span on November 22. The time required for reconstruction of this leaf was therefore 68 days, whereas it required 82 days on the first span rebuilt.

The approximate weight of each new moving leaf is as follows:

	Tons.
Structural steel .....	702
Machinery and electrical equipment.....	38
Concrete counterweight, 490 yards or.....	940
Timber floor .....	38
Track, etc. ....	10
Pig iron for counterweight.....	10

Total weight ..... 1,738

This is distributed between two segmental-girders making 869

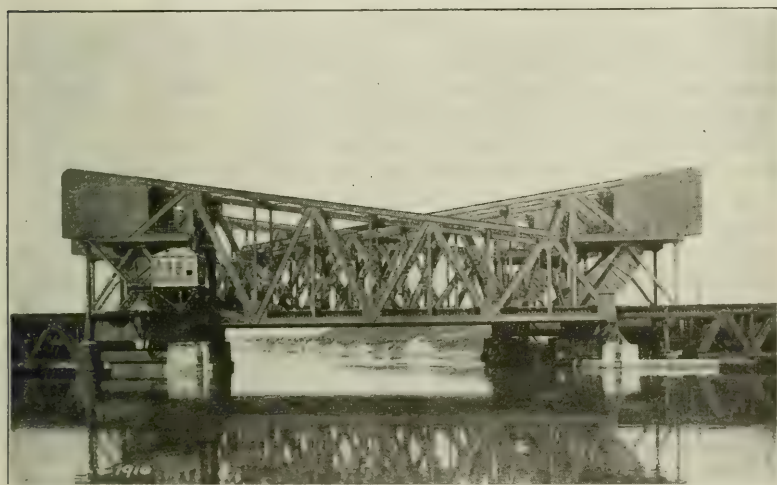


Fig. 13. Eight-Track Bridge Completed.

tons on the perimeter of each girder. The concrete for counterweight was a 1, 3, 6½ mixture of Portland cement, sand, and 1½ in. maximum size crushed stone.

The general contract for the entire work of reconstructing the bridges was let to the Chicago Bridge & Iron Works. The erection was sublet to the Ketler-Elliott Erection Co., the electrical equipment to George P. Nichols & Brother, and the machinery to the Featherstone Foundry & Machine Co., all of the above being located in Chicago. The planing of the track-girders and peri-

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meters of the segmental-girders required special appliances designed for this express purpose, and necessitated very careful and accurate workmanship. We believe that on this part of the work we have secured results not inferior to similar work on any other bridge of this type that has ever been built.

*Note.*—(May 1, 1910). All four spans have been erected and are now in service for traffic, although not yet operated for navigation.

#### DISCUSSION.

*Mr. Geo. T. Horton, M. W. S. E.*—The fabrication of this bridge was quite a pleasure and also quite a lot of work. Outside of the magnitude of the thing, the principal features that we had to contend with were the heavy track-girders and the segmental-girders. The track-girders we had to plane on the top and bottom. That we did with a rotary planer on a fifty-foot bed, which traveled the full length of the girder and I think gave very satisfactory results. For the segmental-girders we built a special machine, which consisted of a rotary milling tool twenty-eight inches wide, and large enough to plane the segments. That was mounted on a radial arm driven by a motor. The segment was put in, leveled up, the thing started, and after running over it a week or so we finally managed to grind it down. We did get fine results. The tracks inside the segmental-girders are ground down to almost a perfect fit and I think there will be no movement or creeping between the girders.

*Mr. T. L. Condon, chairman.*—I was impressed by the illustrations of this work with what must have been the unusual difficulties in handling the parts of the structure in the shop; and I was also favorably impressed by the repeated statement made by the speakers that here, there and elsewhere they had no trouble doing so-and-so. It is not unusual to have very considerable trouble in the field with a structure that has so many unusual and difficult features; and if the work came out of the shop in such shape that the engineers, representing the Sanitary District, repeatedly say that they had no trouble in the field, I think it is a high compliment to the manufacturers.

*Mr. Andrews Allen, M. W. S. E.*—I was impressed with Mr. Horton's method of planing the segmental-girders and the track-girders. That is one feature that has not been adequately handled in previous bridges of this type. There has always been more or less difficulty in the creeping of the track and breaking down of the angles connecting the track with the segmental-girders. It looks to me as though those things are going to stand in this case, and I am sure that credit is due both to the Sanitary District and the manufacturers in this respect.

*Mr. T. L. Condon.*—I wish to ask Mr. Kandeler if the Terminal Transfer R. R. bridge at Taylor Street is not the longest Scherzer bascule bridge that has been built.

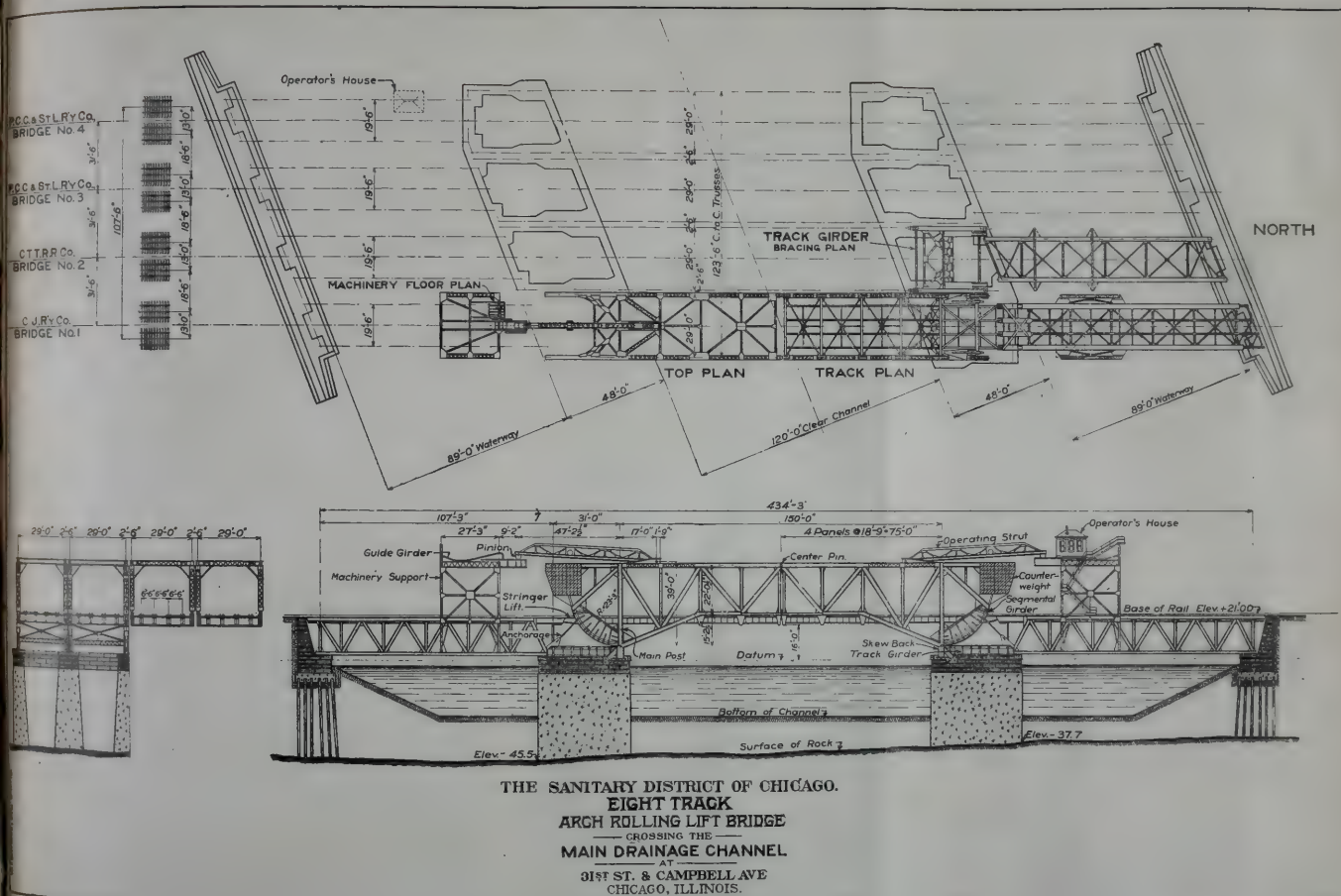
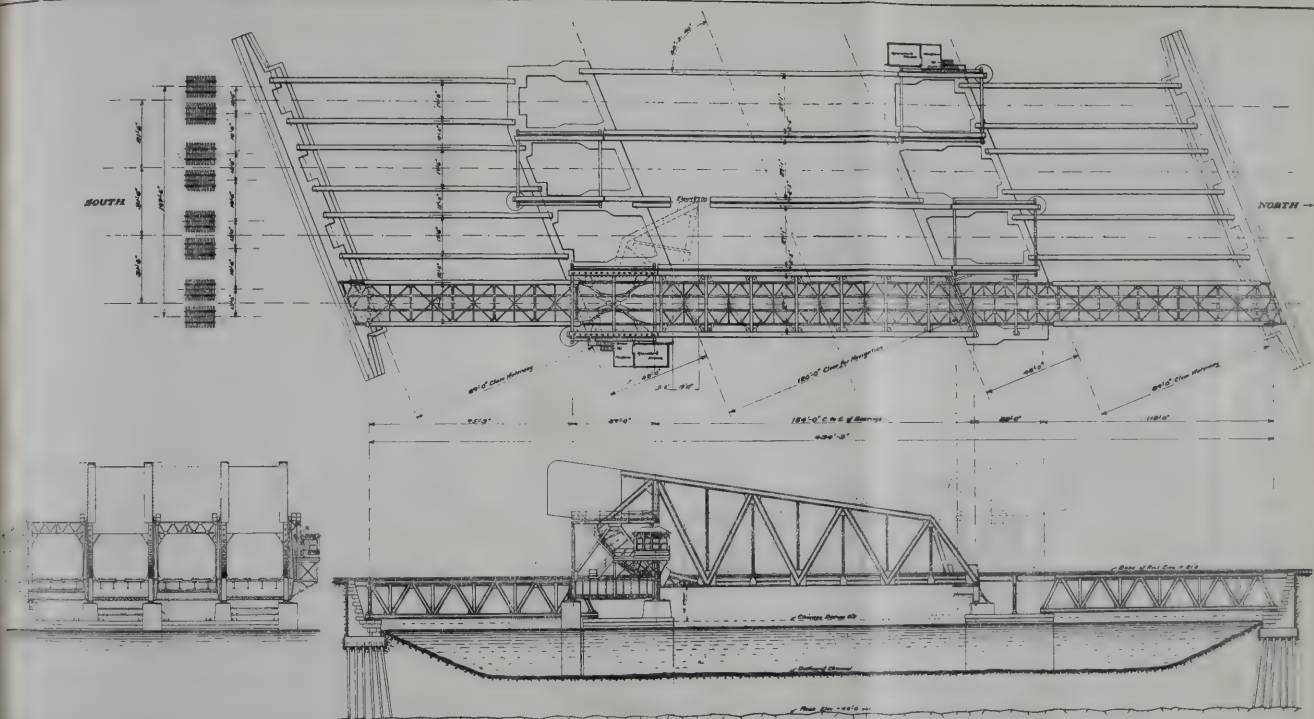


Fig. 2. Original Bridge as Planned to be when Completed.





**SANITARY DISTRICT OF CHICAGO**  
**EIGHT TRACK**  
**SCHERZER ROLLING-LIFT BRIDGE**  
 FOUR SINGLE LEAF DOUBLE TRACK SPANS  
 FOR THE  
**P.C.C. & ST. L. RY. CO. - C.T. & R. CO. & C. & N. RY. CO.**  
 CROSSING THE  
**MAIN DRAINAGE CHANNEL**  
 • 31st ST. & CAMPBELL AVE. •  
 CHICAGO, ILL.

PREPARED BY  
**The Engineering & Planning Co.**  
 100 N. WABASH ST., CHICAGO  
 DRAWN BY J. H. HARRIS  
 CHECKED BY J. H. HARRIS  
 SCALE: 1" = 10' HORIZ. 1" = 10' VERT.  
 MAY 1910

Fig. 3. New Bridge of Single Leaf Spans.







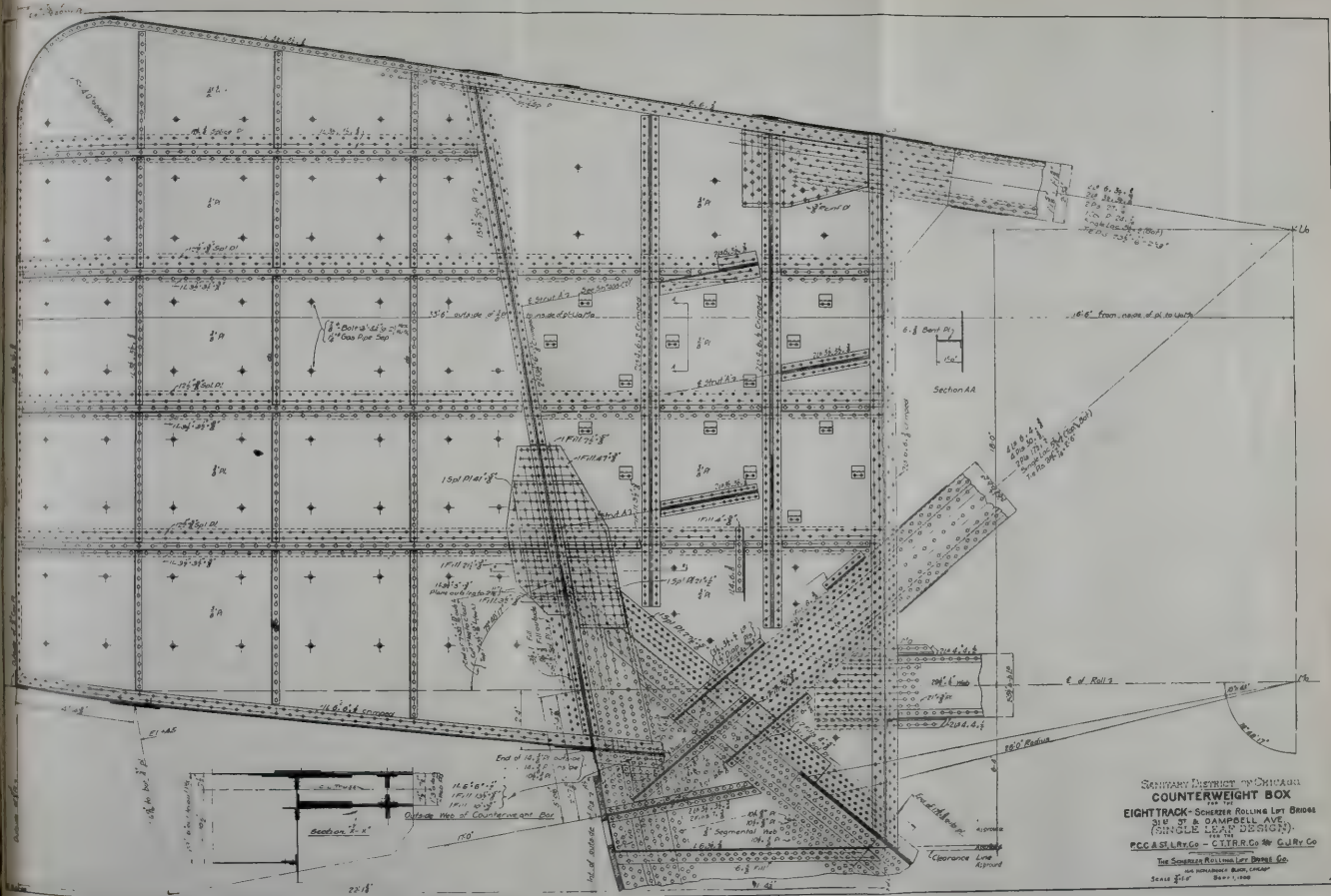


Fig. 5. Counterweight Box.



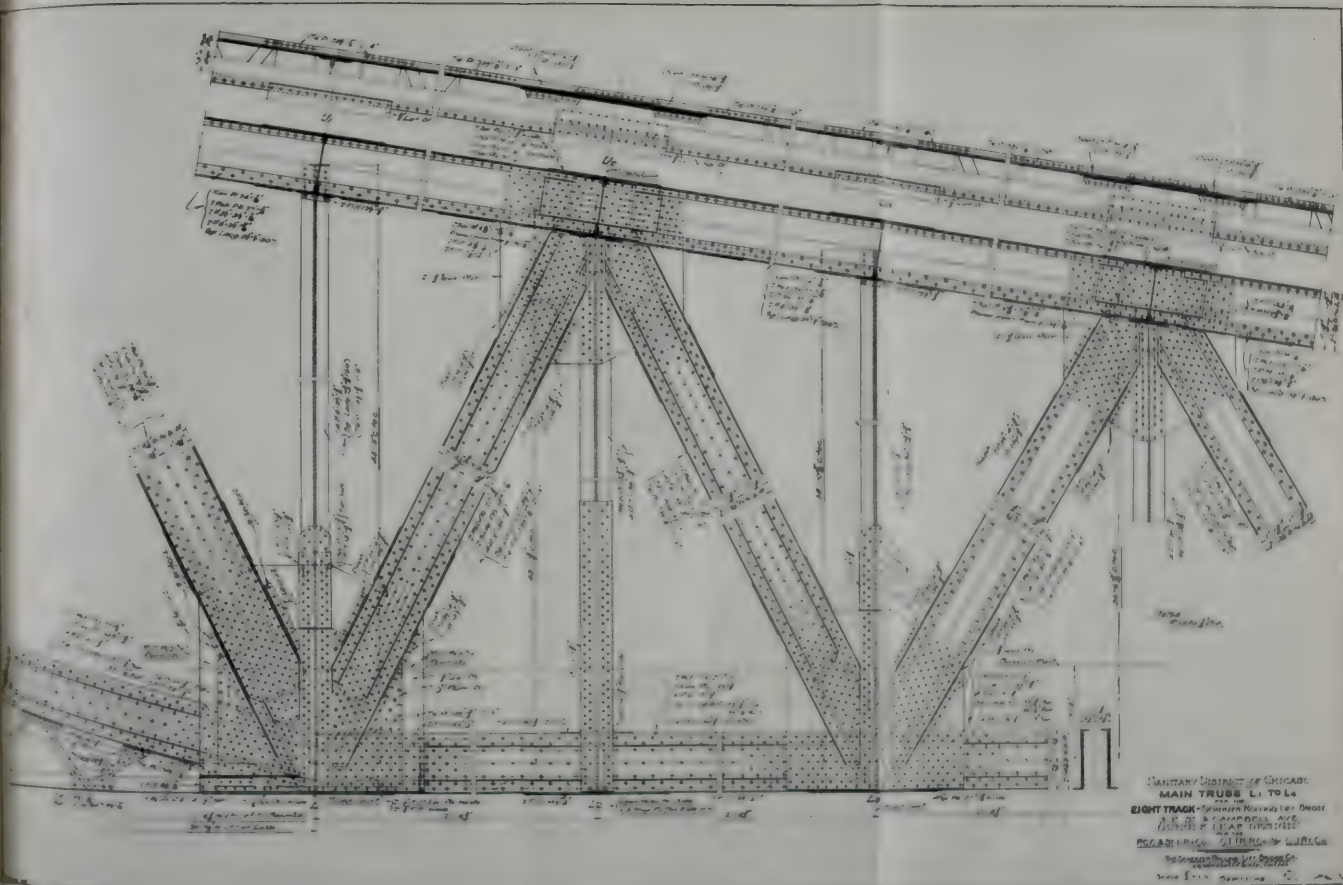


Fig. 6. Details of Main Truss.



*Mr. Theodore Kandler:*—The Terminal Transfer R. R. bridge is 275 ft. long between centers of bearings, and is the longest span bascule bridge ever built. This was built some years ago and there was lack of experience then; the special uncertainty was the fastenings of the track-plates placed on the track-girders, under the rolling segments. When a wheel rolls on a rail both the rail and the rim of the wheel will be bent to a certain extent, and it is very hard to tell how this bending will affect the connection of the rail and the connection of the rim. Assumptions had to be made to figure these, and in later years these fastenings have been made much stronger than in the earlier bridges.

*Mr. Allen:*—I wish to ask Mr. Dart or Mr. Smetters what formula they use for calculating the distribution of load on the tracks.

*Mr. Dart:*—We use an empirical formula for the bearing.

*Mr. Kandler:*—The theory of the bearing of the wheel on the rail is not completely developed. Some experiments have been made lately which show that the bearing in the older bridges of this type was insufficient, but I do not think there is a perfect theory that is accepted by the profession.

*Mr. Smetters:*—Present ideas differ materially, but in designing the segmental and track-girders we assumed that the material, under high stress, is restrained from deformation by the surrounding material which is under little or no stress. That is the basis of our theory. This condition is indicated in straightening metal plates. A steel plate can be straightened if worked from the side, toward the center, but it is practically impossible to straighten a plate by working outward from the center. I give this as an illustration to show that when material is restrained in this manner it is hard to change its shape.

*Mr. E. N. Layfield, M. W. S. E.:*—I wish to call attention to a fact that I think has not been sufficiently emphasized in this discussion, that this bridge takes the place of a double-leaf bridge which was built about eight years ago and was completed to the extent that it could be used as a fixed bridge, the segmental and track-girders and machinery being omitted and the intention being to add them later and make it a movable bridge. It was shown by careful study that it was more economical to tear out the original bridge entirely and put in a new bridge. This appealed forcibly to the representatives of the railroad companies, of which I happened to be one, for the reason that the center lock in a two-leaf bascule bridge is very objectionable from the standpoint of operation. It was very satisfactory to the railroad men to have this bridge changed from a two-leaf span to a single-leaf span.

I have received quite a number of letters from bridge engineers all over the United States and outside of the United States, concerning the center lock on our big bridge near Taylor Street. That lock, I believe, is a very good design, as good as any that I have

seen for such a purpose; but it is impossible, I think, to make a center lock in a two-leaf bascule bridge that is thoroughly satisfactory for railroad service. Necessarily the load on one leaf has to be carried over to the other leaf, and a movable lock is hardly a practicable thing for railroad service. It would have to be, of course, a very heavy and expensive device in order to carry the weights that go over such a bridge. I received a letter from the bridge engineer of one of our large railroad systems, in which he asked my opinion as to the practicability of putting a tension lock in the bottom chord of such a bridge. I understand that several such designs have been gotten up, but it seems to me that this is something that it would be practically impossible to accomplish; and our experience with the big bridge referred to at Taylor Street is sufficient to make me say that anybody building a bascule bridge should not only strain a point, but strain it to the utmost, to make the span a single-leaf, even if it is carried to the extreme limit of the span that can be built. This lock that I speak of has not given us any serious trouble; but it is something that has to be watched very carefully and it is subject to possible accident at any time in a way that an ordinary movable bridge is not subject to.

Regarding the breaking down of the track-girder or the segmental-girder, there has been a great deal said about the breaking down of the rolling-girders, particularly with respect to this bridge; but the trouble that we have had with the breaking of the bolts has been largely overcome by simply putting in larger bolts and more of them. We have within the past year doubled the number of bolts and made them somewhat larger. When these bolts were put in, I used Swedish iron and steel for the purpose of ascertaining if the Swedish iron bolts would be better. They cost us very much more than the steel bolts, and I am having figures made now as to just what the cost was. Since they were put in I have not been able to observe any difference between the Swedish iron bolts and the steel bolts, because none of them have broken.

## IN MEMORIAM.



**ARTHUR B. CROZIER, M. W. S. E.**

Died November 7, 1909.

Mr. Arthur B. Crozier was born in Anderson county, Kansas, August 26, 1875, and died in Kansas City, Mo., November 7, 1909, following a brief illness from typhoid fever.

Mr. Crozier was graduated from the State University of Arkansas in June, 1897, having taken the course in Electrical and Mechanical Engineering. Immediately after graduation he became active in engineering work, first associating himself with the Electrical Construction Co., of Little Rock, Ark., and a little later with the Fayetteville electric lighting plant and telephone system. He was also superintendent of the Eureka Electric Railway & Lighting Company of Eureka, Ark., for about two years. He came to Kansas City, Mo., in January, 1899, spending about a year with the Ozburn Electrical Construction Company, of Kansas City; later he served a short connection with Waddell & Hedrick, bridge engineers, and also Rudolph Margraf, architect, in the designing of Woolf Bros. laundry—one of the largest steam laundries in the West. In 1900 he spent some time with the Kansas City Belt Railway and with the Metropolitan Street Railway Company of Kansas City, and in the fall of 1900 he began working for the Schwarzschild & Sulzberger Packing Company, which company sent him to Chicago in 1901, where he remained with them through all of the important construction work on their Chicago plant. He was then promoted by them to the position of chief engineer and later to the position of master mechanic. While holding this position, he was sent by the packing company to their New York plant.

Mr. Crozier was married October 7, 1903, to Miss McKie Young, of Lexington, Mo. In 1903 he severed his connection with the Schwarzschild & Sulzberger Packing Company and entered the employ of Solitt Bros., general contractors of Chicago, August, 1910

cago, and later was employed by B. J. Arnold & Co. of Chicago. In 1905 he was selected by the Cudahy Packing Company of Omaha as master mechanic for their Omaha plant, which position he held until 1908, when he entered business for himself as Consulting Mechanical Engineer with offices in the Kansas City Life building, Kansas City, Mo. His previous varied experience made him especially well fitted for consulting engineering practice for mechanical work, and he was entrusted with many important engagements in his private practice, some of the most important being the Kansas City Galvanizing Company's plant, and the Kansas City Scraper Manufacturing Company works. At the time of his death he was consulting engineer for the Ferromatic Tire Company, and a number of other companies erecting manufacturing plants. One of his important engagements was that of consulting engineer for the new Y. M. C. A. building of Kansas City, Mo., where he had responsible charge of the entire lighting, power, and heating plant. The work that he performed for the Y. M. C. A. building committee was much appreciated by them, and his valuable assistance in this work enabled the building committee to construct a plant that has been the source of much pride on the part of the officers of the Y. M. C. A. He took a keen and active interest in all matters pertaining to the up-building of the Y. M. C. A., conducting classes in engineering during the winter seasons.

Mr. Crozier was elected as a member of the Western Society of Engineers, March 18, 1904. The engineering profession of Kansas City feels a distinct loss in the death of Mr. Crozier, as he had many friends and was held in high esteem by all with whom he came in contact. He is survived by his wife and two children, who now live at Lexington, Mo., and the sincere sympathy of the members of the Society is extended to them.

ROBT. E. McDONNELL, M. W. S. E.  
Committee.

# PROCEEDINGS OF THE SOCIETY

## REQUIREMENTS FOR THE PREPARATION OF PAPERS.

The Publication Committee of the Western Society of Engineers calls attention to the following requirements in the preparation of papers, and rules for their presentation. The work of the Society will be facilitated if authors, in the preparation of their papers, will observe the following rules:

1. The number of illustrations accompanying a paper, in those cases where engravings are required, should be sufficient for a proper presentation of the subject. The number offered, however, should be limited to those actually required to show the novel or essential features involved.

2. Drawings should be so prepared that when they are reduced in the process of making engravings, the various details will be large enough to be readily seen. The size of a page of the Journal is 4 in. by 7 in., and all drawings should be made so that they will reduce to a length of 4 in. when they are to be set crosswise of the page, or to a length of 7 in. by 4 in. high if required to be set lengthwise. It is desirable to limit the size of engravings to one page, but in special cases, when necessary, engravings may occupy more than one page, in which case they will be printed on a folder which will be inserted in the Journal. In making drawings, the letters, figures, and lines should be of such size and weight that when the reduction has been made they will appear of a convenient and proper dimension. For example, a drawing 16 in. long to reduce to 4 in. would reduce to one-quarter of its original size, so all figures, lines, and letters should be made four times as heavy and large as they should appear when in the reduced form. A caption should be placed under each illustration; it should be as short as possible, yet clearly descriptive.

3. Authors should confine their manuscript to the main features of the subject, avoiding the introduction of unessential description and statement, as far as possible. All manuscripts will be subject to editorial revision.

4. An abstract or conclusion should accompany the paper wherever practicable, preferably as an introduction, as it will present the substance of the paper to those interested without its being necessary to read all of it. In the presentation of tests and experiments, the results may often be expressed in a measure of efficiency or cost which may be readily noted. In other types of papers certain conclusions are derived as a result of experiment or experience, and can be presented in like manner. This plan is desirable, as the results given in a paper are thus made readily obtainable for reference without going through the paper to find them.

5. Titles of papers should be self-explanatory and the first word should be significant of the subject. For illustration, *Some Results Due to Improvement in Boiler and Furnace Design* would be better presented as *Boiler and Furnace Design; Some Results Due to Improvement*, as it would index under the word boiler, which is significant of the subject.

6. In papers where mathematical formulae are employed in presentation of the subject, it is suggested that so far as is consistent with clearness the formulae be presented in an appendix, and that the author's argument or conclusion be given as far as possible in the vernacular, so that it will not be necessary to interpret mathematical expression to ascertain the author's meaning. Thus the simple statement of the proposition may be made with a reference to the corresponding formulae, which may be found in the appendix. This is desirable because readers, as a rule, do not wish to interpret mathematics in obtaining the substance of a paper.

7. It is suggested that authors, in the preparation of manuscript, consider the fact that many members of the Society who may follow different lines of engineering work than that of the author, may not be especially familiar with the state of the art in the line of work which the author is treating, and therefore fail to derive as much benefit from the paper as they would if the author had taken this fact into consideration. To illustrate: an electrical subject should be presented so that it will be grasped by engineers following other lines of work. Likewise, with a subject in

civil engineering, certain points well known to engineers in that field should be made clear to those working particularly in other lines. There is a natural disposition to write for the information of those who are already quite familiar with the subject, but it is thought desirable to take into consideration the interests of the membership at large, as far as possible.

### **RULES FOR PRESENTATION OF PAPERS**

1. When papers are printed and circulated in advance, the author shall be limited to 45 minutes in the presentation of his subject.

2. Authors, or other persons, should furnish the presiding officer with a list of people who may be called upon during the meeting for discussion, as a definite program is conducive to a clear, full, and harmonious presentation of the subject.

3. The presiding officer should require those who volunteer discussion to address the chair and state their names so that the stenographer may be able to include them in the notes. This is a feature which may give considerable trouble if not followed, as it is sometimes impossible to afterward ascertain the identity of a speaker, especially if he be a visitor.

4. It is desirable, as far as possible, that the author confine his remarks to the introduction, presentation of the paper, and closure which latter should preferably be given after all the discussion has been offered, unless it is necessary for a speaker to have some point of information to assist him in presenting his argument. This plan is generally more desirable than having the discussion interrupted by questions and answers. The presiding officer will occupy the platform at all times during the meeting, except when the author has it for the presentation of his subject.

5. Upon presentation, all papers shall be given to the public press for publication in full or in abstract upon condition that the Society and its Journal be given due credit. Discussion of papers shall be given to the press upon presentation, if the one offering the discussion so desires or consents. Otherwise discussion will not be given to the press until two weeks after its presentation, to enable correction to be made in it, if necessary.

**Approved by the Board  
of Directors, Aug. 2, 1910**

**THE PUBLICATION COMMITTEE.**

## ABSTRACT OF THE MINUTES OF THE MEETINGS.

*Wednesday Evening, June 1, 1910.*—Regular meeting (No. 704) of the Society, called to order at 8:20 p. m., Vice-President Bement presiding and about forty members and guests in attendance. Minutes of meetings of May 4th and 18th read and approved. Reported from the Board of Direction, the election into membership of the following:

T. E. Richards, Jr., East St. Louis, Ill.....	Junior
C. E. Henderson, Urbana, Ill.....	Active
George W. Horn, Chicago.....	Active
Frank D. Chadwick, Spring Valley, Ill.....	Active
Henry H. Courtney, Chicago.....	Active

Applications for membership received from:

Edwin S. Mills, Chicago.

D. H. Maxwell, Chicago.

Mr. Dwight C. Morgan, M. W. S. E., by letter, presented to the Society as a memorial of his father, the engineering library of the late Richard Price Morgan, M. W. S. E., the accumulation of sixty years of professional service. Accepted by the Society with a vote of thanks to Mr. Morgan.

The engineering library of Past-President Gen. Wm. Sooy Smith was offered the Society, to make such disposition as they see fit, as he retires from engineering work and moves to Oregon. Accepted by the Society with thanks.

A report was presented from the joint committees of five members of the Society and corresponding members from the Architects' Business Association, and the Masons' and Contractors' Association, which had been appointed to prepare and establish rules for the measurement of concrete work, foundations, etc. Report accepted with vote of thanks to the committee.

Mr. Warren R. Roberts, M. W. S. E., introduced, who presented his paper, with illustrations, on "Engineering Applied to Modern Coal Mining." Discussion from Messrs. Gayman, Rapp, McCullough, Seely, Giffey, Scholz, and Rasmussen. Adjourned at 11 p. m.

*Tuesday Evening, June 7th.*—A joint meeting of the Society (No. 705) and Chicago Section, A. I. E. E., postponed from May 25th, called to order at 8:25 p. m., Mr. G. T. Seely presiding, and about sixty members and guests in attendance. Minutes of last preceding joint meeting read and approved.

Mr. F. Darlington, of Pittsburg, introduced, who presented in abstract his paper on "Selection of Electric Railroad Apparatus." Discussion from Messrs. Abbott, Jackson, Jenks, Bement, Lake, Lukes, Renshaw, and Brady. Closure from Mr. Darlington. Adjourned 11 p. m.

*Wednesday Evening, June 15th.*—Extra meeting (No. 706) of the Society, called to order at 8:15 p. m., with Vice-President Bement presiding and about forty members and guests in attendance. Resolution offered by Mr. E. McCullough that the meeting of the Society be omitted during July and August. Adopted.

Mr. C. P. Berg, M. W. S. E., introduced, who presented his paper on "Heat Treatment of High Speed Tools," illustrated. Discussion from Messrs. Pierrefeu, Prentiss, Lowrie, Going, Touzalin, Aston, Mayer, Young, Kellogg, Mershon, and Myall. Closure by Mr. Berg. Adjourned 10:30 p. m.

*Friday Evening, July 8th.*—A special-extra joint meeting, (No. 707) of the Society, and Chicago Section, A. I. E. E., called to order at 8:25 p. m., with Vice-President Bement presiding, and about sixty-five members and guests present.

Mr. A. W. Blonck, Assoc. A. I. E. E., addressed the meeting on "Recent European Progress in Dirigible Balloons," with illustrations. Discussion from Messrs. Symons, Lake, Cravens, Finley, Foster, Mayer, and the chairman. Adjourned at 10:00 p. m.

J. H. WARDER, Secretary.

August, 1910

## LIBRARY NOTES.

The Library Committee desires to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

### GOVERNMENT.

- Library of Congress—
  - Preliminary List of Subject Subdivisions. Pam.
- Bureau of Census—
  - Mortality Statistics, 1908. Cloth.
- U. S. Geological Survey—
  - Bulletins Nos. 398, 417, 428.
  - Water Supply and Irrigation Papers, Nos. 239, 241, 243, 244, 245, 248, 249, 252.
  - Geological Atlas, Nos. 169, 170.
  - Building Operations in the Leading Cities of the U. S., 1909. Pam.
  - The Movement of Lake Superior Iron Ores, 1909. Pam.
- Department of Commerce and Labor—
  - Pilot Rules and Laws Governing Steamboat Inspection. 5 pams.
- Interstate Commerce Commission—
  - Twenty-third Annual Report, 1909. Cloth.
  - Statistics of Railways in the U. S., 1908. Cloth.
- U. S. Civil Service Commission—
  - Annual Report, July 1, 1908 to June 30, 1909. Cloth.

### EXCHANGES.

- Ontario Bureau of Mines, Toronto—
  - 18th Annual Report, 1909. Cloth.
- Massachusetts State Board of Health—
  - 40th Annual Report, 1908. Cloth.
- Illinois Geological Survey—
  - Bulletins Nos. 13 and 14. Cloth.
- Lawrence, Mass., Water Board—
  - Annual Report, 1908. Pam.
- New Jersey Commissioner of Public Works—
  - Annual Report, 1909. Cloth.
- Engineering Association of the South—
  - Proceedings, First Quarter, 1910. Pam.
- Royal Scottish Society of Arts—
  - Transactions, Vol. XXVIII. Pam.
- Victorian Institute of Engineers, Australia—
  - Proceedings, 1909. Cloth.
- Canadian Society of Civil Engineers—
  - Report of Annual Meeting, 1910. Pam.
  - Year Book and List of Members, 1910. Pam.
- Canada Department of Mines, Ottawa—
  - Annual Report, Division of Mineral Resources, 1907-8.
- New York State Engineer and Surveyor—
  - Report of Advisory Board of Consulting Engineers, 1909.
- New York Public Service Commission, First District—
  - Reports of Board of Rapid Transit Commission of City of New York, 1905-6. Paper.
- Institution of Electrical Engineers, London—
  - Journal, May 1910. Pam.

- Iowa Engineering Society—  
 Proceedings, 22d Annual Meeting, 1910. Pam.
- Geological Survey of Ohio—  
 The Middle Devonian of Ohio, Bulletin 10. Pam.
- University of Illinois, Water Survey—  
 Chemical and Biological Survey of the Waters of Illinois.  
 Pam.
- Illinois Society of Engineers and Surveyors—  
 25th Annual Report, 1910. Pam.
- Massachusetts Railroad Commissioners—  
 41st Annual Report, 1909.
- Institution of Mechanical Engineers, London—  
 Proceedings, October to December, 1909. Pam.  
 List of Members, 1910. Pam.
- Metropolitan Water and Sewerage Board, Boston—  
 9th Annual Report, 1909. Cloth.
- Maryland Geological Survey—  
 Annual Reports, 1908 and 1909. 2 Vols. Cloth.
- American Society of Civil Engineers—  
 Transactions, June, 1910. Pam.
- American Institute of Mining Engineers—  
 Transactions, 1909. Pam.
- Canadian Society of Civil Engineers—  
 Transactions, October to December, 1909. Pam.
- West Virginia State Geologist—  
 County Reports, Pleasant, Wood, and Ritchie Counties,  
 1910. Cloth.
- North of England Institute of Mining and Mechanical Engineers—  
 An Account of Strata of Northumberland and Durham  
 Borings and Sinkings.
- State Highway Commission, Columbus, Ohio—  
 4th and 5th Annual Reports, Leather. (1908-9.)
- Lowell Water Board, Lowell, Mass.—  
 37th Annual Report, 1909. Pam.
- Lawrence Water Board, Lawrence, Mass.—  
 Annual Report, 1909. Pam.
- Boston Society of Civil Engineers—  
 List of Members, 1910. Pam.
- Illinois Board of Charities—  
 Quarterly Bulletin, December, 1909. Pam.
- Rhode Island Commissioner of Dams and Reservoirs—  
 Annual Report, January, 1910. Pam.
- Nova Scotia Institute of Science—  
 Proceedings and Transactions, Vol. XI, Parts 1, 3, 4.  
 3 Pams.
- Engineering Association of New South Wales—  
 Proceedings, 1908-9. Cloth.
- Institution of Engineers and Shipbuilders in Scotland—  
 Transactions, 1908-9. Cloth.
- Institution of Electrical Engineers, London—  
 Proceedings, June, 1910. Pam.
- Society of Engineers, London—  
 Transactions, 1909. Cloth.
- Illinois State Geological Survey—  
 Bulletin No. 15. Cloth.
- Connecticut Society of Civil Engineers—  
 Proceedings and Transactions, 1909. Pam.
- Engineering Association of the South—  
 Proceedings, May-June, 1910. Pam.

August, 1910

American Society of Agricultural Engineers.  
Transactions, 1907 and 1908. 2 Pams.

## GOVERNMENT.

Department of Commerce and Labor—  
Statistics of Cities Having a Population of over 30,000.  
1907. Folio.

Library of Congress—  
Classification Outline Scheme of Classes. Pam.  
Classification Class "Z." Bibliography and Library  
Science. Pam.

U. S. War Department—  
Annual Report of Chief of Engineers, Vol. 5, 1909. Cloth.  
Annual Report of Chief of Ordnance, Vol. 6, 1909. Cloth.  
Annual Reports of Chiefs of Departments, 1909. 7 Vols.

U. S. Geological Survey—  
Geological Atlas Nos. 167, 168.  
42 Topographical Maps.  
Bulletins Nos. 406, 407, 420, 422, 428.

Interstate Commerce Commission—  
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## BOOK REVIEWS.

**A HISTORY OF THE LOGARITHMIC SLIDE RULE AND ALLIED INSTRUMENTS.** By Florian Cajori, of the Colorado College, School of Engineering. 5 by 7 ins.; pp. 126 plus X; 17 illustrations. Cloth bound. Price, \$1.00. The Engineering News Publishing Co. New York, 1909.

Those who make frequent use of that labor saving device, the Slide Rule, will find much of interest in this historical sketch. This history goes back to the invention of Logarithms by Napier in the latter part of the sixteenth century. It was a natural step in evolution, that, having a series of logarithms of numbers, these should be laid down as scales. So that by their use mechanically, computations could be made with a saving of mental effort. Gunter's Scales appear to have been the first development of these devices. It was a simple step from the use of compasses to take off one quantity from one scale and apply it to another scale, in computation, to accomplish the same thing by having the scales arranged to slide past each other and thus avoid the necessity of using compasses. From this book it appears that even prior to 1800 the use of such scales was very popular in England, and used extensively. The author shows the development in England, in Germany, and in France during the eighteenth century. Subsequently he traces the development in these countries and in the United States during the nineteenth century.

Among the more modern forms described is that of Edwin Thacher, invented nearly thirty years ago. In this instrument the line of logarithmic scales is greatly extended by constructing it as a spiral line about a cylinder. In construction, this cylinder carrying the graduated lines is placed inside a circular cage of parallel bars (virtually elements of the inner cylinder), which carry the other scales. In his earlier work, Mr. Thacher drafted these scales by hand on paper, which, when rolled up, constituted the circumference of the cylinder which he had made by a tinsmith. It was difficult to get the tin cylinder sufficiently accurate in diameter and as a true cylinder to fit the sheet of paper containing the scales. The reviewer, to whom Mr. Thacher was showing the device and telling of his troubles, had the honor of suggesting the use of die-drawn brass tubes for the base of the cylinder of the instrument. In more recent years the instrument makers have improved in the manufacture of slide rules of the Mannheim type, which was first devised about 1850. These are more readily handled and carried about by an engineer on his person, and are also far less expensive than the Thacher cylindrical slide rule, but this latter is valuable for office use and at the desk.

In the book under review there are some sixteen pages of "A List of Slide Rules Designed and Used Since 1900," with notes as to the inventor, where described, etc. Following this are fifteen pages of "Bibliography of the Slide Rule" that completes this interesting little book. It is well worth the very moderate price asked for it.

**ORNAMENTAL CONCRETE WITHOUT MOLDS.** By A. A. Houghton. The Norman W. Henley Publishing Co., New York, 1910. Cloth; 5 by 7½ ins.; pp. 132, including index; 30 illustrations. Price, \$2.00.

The author of this book has also written on "Practical Uses of Concrete," "Concrete from Sand Molds," and "Clay Models and Plaster Molds for Ornamental Concrete."

There are many objects for which concrete is an admirable material for construction. This includes drinking fountains, tables, columns, pillars, posts, etc. Examples of such work may be seen in Lincoln Park. When such objects can be resolved into solids of revolution, they may be formed of concrete very much as the original copy would be made of wood turned up in a lathe. In concrete construction the plastic material is worked up and shaped by an outside former revolved about the central axis of the object, "struck up," it might be said, by means of a swinging templet. The application of the templets and small forming pieces is not limited to the above, but many other

things may be made, as shown by the author in this little book. One point in this book is the illustration of templets for ornamental work drawn to a scale with dimensions so that the artisan can lay off the proportions of the several points that go to make up a column, capital, pedestal, and the like. The book is essentially for the practical worker in concrete, and doubtless there are many concrete workers who could make use of a portion of their plant in bad weather or winter-time by making up such objects of concrete for sale at other seasons of the year.

**CONCRETE PLAIN AND REINFORCED.** By Frederick W. Taylor and Sanford E. Thompson. Second edition, XI, 807 pages, 249 plates and diagrams, 9¼ in. by 6¼ in. Cloth. John Wiley & Sons, New York. Price, \$5.00.

When the first edition of this book came out in 1905, the literature on this subject, in this country, was somewhat widely scattered. The book then filled a need, and although somewhat unsatisfactory on many points, yet it was adopted and was still held by many to be the most reliable source of information until this second edition.

The new edition is a great improvement over the old one as it covers the entire field of information upon the subject bringing the book up to date. Many points unsatisfactorily answered in the first edition are much more definitely answered in the present edition. A young engineer, or an old engineer in a new field, wish for definiteness in their information. After discussing a subject pro and con they like to have the writer, who, it is natural to suppose is an authority, sum the matter up and give a definite opinion instead of leaving the reader to decide after reading several pages of conflicting opinions. One would frequently put the old edition back on the shelf with a feeling of dissatisfaction, but with the new edition, it is quite different.

The first part of the book on materials of concrete is unusually full and good. No library upon the subject would be complete without a copy of this second edition. It is the best book in print for the beginner in the subject of concrete and reinforced concrete. Yet, as probably the authors are willing to admit, there is still room for further improvement. There is a little appearance of scrappiness about the book, many things could have been rearranged and condensed, tables and diagrams to text are repeated in two or three places, some page references are incorrect, and some illustrations appear to be taken from studies and not from final working conditions; to mention one only, on page 267, the reviewer thinks the controlling gates from "bin to hopper" could hardly be successfully operated by means of a cord running over pulleys. This portion of the book, however, can be heartily commended and a much more comprehensive study of plant and plant operation (not studies) with plant costs, both as to cost of operation and cost of plant and installation based on yardage handled, would be very profitable.

The chapter on Reinforced Concrete Design is a very great improvement over the first edition and many tables and diagrams are given to aid the designer to meet any condition. The reviewer, however, as is natural, considers his methods as far more elastic and much easier of application.

Taking the general formula  $d = \sqrt{\frac{M}{Rb}}$  or for uniform load  $d = \sqrt{\frac{WL}{8Rb}}$

with a diagram such as is found in Turneaure and Maurer's "Principles of Reinforced Concrete Construction," pages 275 to 278, giving the values of  $R$  and aided by a slide rule, almost any possible condition can be met by merely changing any one of the quantities under the radical, and when a satisfactory  $d$  is found it is extremely simple to take the steel required directly from the slide rule, thus the many diagrams and tables are eliminated. For slabs, however, a table is very convenient, but the reviewer prefers tables like the following greatly extended.

There is nothing whatever said about deflection, although nearly all specifications require a limiting deflection, for approval of the work.

August, 1910

The chapter on Arch Design is apparently a clear cut exposition of the subject and is a valuable addition. The chapter on Retaining Walls appears good, yet something could have been said as to the relative economy of the "T" shaped wall and the wall with counterforts. We sometimes find low walls (10 or 12 feet high) being designed with counterforts where a "T" shape, or under certain conditions, the gravity type, without reinforcing, would be cheaper. Almost nothing is said about a few large fields in which concrete is being used as grain elevators, coal pockets, stone bins, docks, or sea walls. Nevertheless, with all the adverse criticism that different individuals might offer, the book is worth the money to the experienced man and is almost indispensable to the beginner.

W. A. H.

**MODERN LOCATION OF STANDARD TURNOUTS.** By C. M. Kurtz, Construction Department, Southern Pacific Co. Published by the Author, San Francisco, Cal. Leather. 6 $\frac{3}{4}$  in. by 4 in. 51 pages.

This little book appears to be written to promulgate a variation of standard practice by the putting in of a tangent of varying length beyond the frog of a turnout.

The author is not very consistent in that where his turnouts come from the inside or outside of a curve on a main track, he leaves the main track curved, but puts a straight track in his turnout. All of Chapter III, is taken up with cases of this kind.

There is no suggestion in the book that it would be very good practice to eliminate turnouts from curves, especially from the outside of curves wherever it is possible to do so. Nor are the various methods outlined of laying out and doing track work consistent with the usual methods in vogue and some of the methods recommended would appear to be very awkward to carry out, occasioning unnecessary field work.

Chapter V, on the "Traverse Method," does not seem in any way to have any application to the remainder of the book and merely to be thrown in as filling. There seems to be nothing in this chapter which cannot be found in any book on land surveying.

The Turnout and Crossover Tables are too limited in extent to be of much use, except in a few cases where the various frogs and distances are standard on some particular road. There is likely to be very few roads in the country to which they would be applicable.

The book is quite interesting, but the formula and tables would be used in too few cases to make it valuable for a field book and would only be of use as a reference for particular cases.

G. M. B.

**HAND BOOK OF COST DATA FOR CONTRACTORS AND ENGINEERS.** Halbert P. Gillette, Managing Editor, Engineering-Contracting. The Myron C. Clark Publishing Co., Chicago and New York, 1910. Second edition, 5 in. by 7 in., 1,854 pages, including index. Leather bound. Price, \$5.00.

The first edition of this valuable reference book was issued in 1905 and attracted a good deal of attention when it came out, being favorably noticed in most of the technical and in some other publications. This second edition has been greatly enlarged, containing about four times as much material. It is now almost too big to be called a "hand book," being 2 $\frac{1}{4}$  in. thick, but there is so much value in it that one would not wish it to be reduced; and perhaps it is hardly a book that needs to be carried in the pocket for frequent reference. Its place is on the desk, or at least near at hand, so it can be easily referred to when one is making estimates for cost of work proposed.

The book, after an interesting introduction, begins with a set of definitions relating to Principles of Engineering, Economics, and Cost Keeping that covers 111 pages. This subject is treated in a philosophical and logical way and should be carefully read and assimilated by the young engineer, as well as one engaged in contracting. The fundamental principles of cost keeping, with tables and examples worked out, are well set forth. The points to be observed to secure economical work are worthy of close atten-

tion. Methods of keeping cost are also elaborated to some extent; it is this subject that has been so well brought out by Mr. Frank Gilbreth, that makes his books so valuable.

Section II begins at what might be called the foundation work, that is "Earth Excavation," which also includes items of cost of making borings in different situations and kinds of soil, to determine the character of the material below the surface. This occupies fifty-two pages of the book.

Section III, as a natural sequence to the preceding, relates to rock excavation, quarrying and crushing. This chapter contains many tables of value bearing upon the subject. There are eighty-eight pages of this matter which also includes the cost of rock drilling, by hand and with machines, including diamond drill work.

Section IV, of 272 pages, pertains to roads, pavements and walks. This chapter is well written with some valuable definitions as an introduction. With recent and growing interest in improved roads, this chapter is valuable to engineers and contractors engaged on road work and also to those who have a general, though perhaps more or less abstract, interest in the subject, as taxpayers who contribute toward paying the bills and hope to have the benefit as users of the road. The subject of keeping down the surface dust of the road is, of course, an important part of this chapter. There are several valuable tables of unit costs of road construction.

Section V is devoted to stone masonry, and consists of fifty-five pages, the first six pages of which give definitions pertaining to the subject. This chapter also contains much valuable cost data pertaining to different masonry work, whether random faced, rubble or coursed ashlar, and includes such items as cleaning, pointing old work, rip-rap work, paving, etc.

The next chapter, Section VI, pertains to concrete and reinforced concrete construction. With the present active interest in this class of construction and the many engineers and contractors so engaged, this chapter of 111 pages will probably be frequently referred to. The cost data refer to concrete in mass, as in dams, locks, retaining walls, and abutments and also to smaller and isolated structures as piles, telephone and trolley poles, fence posts, tanks, cells, etc.

Two important chapters of this book are Section VII, water works of 161 pages, and Section VIII, sewers, conduits, and drains, covering 143 pages. In the waterworks section the cost data cover such items as pipe, pipe laying and trenching for the same, based on the results of work in many different localities. Cost of vaults for valves, of cleaning out pipe, of water pipe, and hydrant maintenance, and of laying submerged pipe, are to be found in this section. Wood stave pipe and reinforced concrete conduits, as well as stand-pipes and elevated tanks of wood, metal, and concrete are shown. The cost of filters and covers for same, as well as maintenance and operation are herein set forth. Reservoirs of varied construction are also considered, making this section of much interest. The chapter on sewers, etc., gives costs of trenching and back filling, by hand and machine; costs of sewer pipe, brick, and concrete, monolithic, reinforced, and in sections; also sewage purification and disposal.

Section IX takes up piling, trestling, and timber work, of 124 pages and begins with a set of definitions and then gives cost data for a great variety of work pertaining to the above subjects including the removal of stumps, grubbing, and planting of trees.

Other sections take up the subjects of buildings, railways, bridges and culverts, steel and iron construction, engineering, and surveys, with the final Section XV, of "Miscellaneous Cost Data." Enough has been shown in the preceding to indicate the comprehensiveness of the book, which is a monument to the author who has shown great industry in collecting, tabulating and presenting to the engineering public this great mass of valuable information. -

W.

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## REINFORCED CONCRETE TRESTLES FOR RAILWAYS.

C. H. Cartlidge, M. W. S. E.

*Presented April 13, 1910.*

In railroad construction in the West and South it was, and is still quite generally the practice to bridge unimportant streams, ravines carrying little or no drainage, bayous, and marshes, with pile or timber trestles. As the cost of timber increases and as the standards of railroad maintenance are raised, it is the practice on most roads to replace these structures, when they become ripe for replacement, with structures of a more permanent character. Where the drainage areas are small, pipes or masonry culverts are often built and the remaining portions of the bridges replaced by an embankment, and at such a low cost as to be economical. But there are, on most roads traversing the Mississippi valley, a great many pile trestles in river bottoms, and over bayous or swamps, which may not be filled and which, if replaced with steel bridges on permanent supports, would be extremely expensive, because of their great length.

These conditions are very familiar to all maintenance engineers on roads traversing this part of the country, and the necessity for retaining the entire existing opening is, in many cases, perfectly obvious. In most of these cases there is no need for spans of any great length, there being neither ice nor drift to catch upon supports placed closely together. For bridges having the characteristics described, many of them of lengths from one hundred to a thousand feet or more, the writer has devised a construction which seems well fitted to replace the timber or wooden pile trestle bridge. As the wooden pile bridge is the cheapest wooden construction possible, it occurred to the writer, when considering how best such structures might be made permanent, to design a reinforced concrete construction, following the main features of the timber trestle.

An investigation of the reasons for the great economy of such a construction as the pile trestle shows that it is largely due to the small amount of work necessary to be done in the field. There are no cofferdams, foundation pits, or falseworks to be built. Very little raw material has to be unloaded and cared for. The members comprising both the substructure and super-



structure are taken out and put in place, often largely by machinery and with a minimum of disturbance of the track and delay to traffic. It was evident that if a construction of permanent materials, having the characteristics mentioned, could be devised, the result would be what was wanted.

A structure embodying these features was built and tested, and with the experience gained, a standard plan was drawn up, which is shown in Fig. 1.

It should be emphasized that this construction is suited only for shallow openings, and it is the writer's practice to limit the height of concrete pile trestles to sixteen feet from ground line to base of rail. For greater heights it is his practice to substitute thin piers for the pile bents, although at considerably increased cost.



Fig. 2. First Concrete Trestle.

In Fig. 2 is shown a view of the first trestle built, and experience in its construction led to the design of Fig. 3 which is in accordance with the standard plan of Fig. 1.

The construction of these bridges in any great length requires some little organization, and the more thorough this is the less will be the unit cost and the better the construction.

In the bridges so far built, concrete piles of two kinds have been used—one being moulded in horizontal forms and the other made by *rolling* in a machine, under the Chenoweth patents. The moulded piles were used in the first of these bridges. They were sixteen inches square at the butt, had a four-inch chamber

at each corner, a taper of four inches in thirty feet on each face, and were pointed at the tip. The reinforcement consisted of four  $\frac{3}{4}$ -in. sq. corrugated bars, hooped with No. 12 gauge steel wire, wound at close pitch near the butt and point, and at three-inch pitch over the greater part of the length of the pile. The reinforcement was assembled on a mandrel and the spiral hooping wound around it by turning the mandrel. After the hooping was in place it was tied at frequent intervals with No. 16 soft wire, and the complete reinforcement was then withdrawn from the mandrel.

The forms were of wood, unlined and made so that the sides could be removed as soon as the concrete was firm; the pile was left on the bottom boards until hard enough to stand handling. The reinforcement was hung in the forms by wires depending from the cross braces and concrete, composed of one part of



Fig. 3. Second Concrete Trestle.

cement to four and one-half parts of gravel, mixed to a slushy consistency, poured in. The gravel was generally screened so that all the sand and pebbles one half inch in diameter or less were retained and used, the coarser aggregate being rejected. The piles were allowed to harden at least thirty days before being shipped. This seems to be about the least time which can be allowed, as attempts to ship and drive piles of less age have not been successful. More extended seasoning is often easily obtained and is to be preferred.

The *rolled* piles are made in the machine shown in Fig. 4.

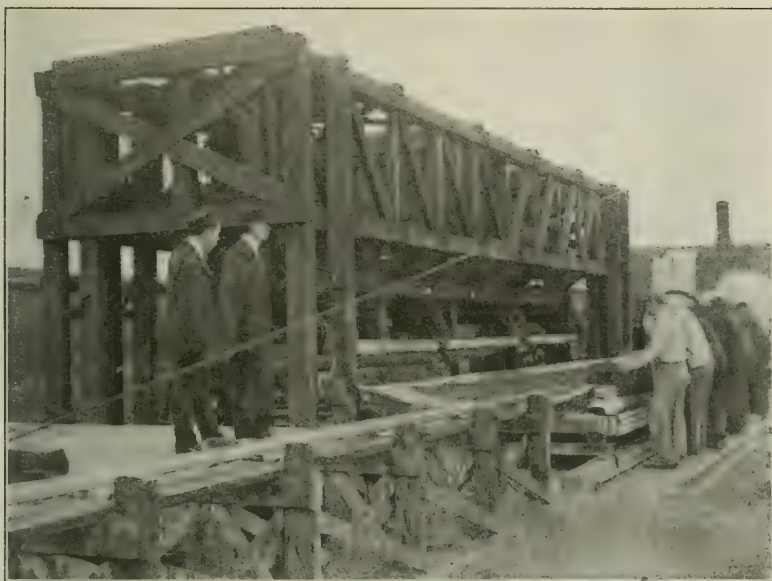


Fig. 4. Manufacture of Rolled Concrete Pile.

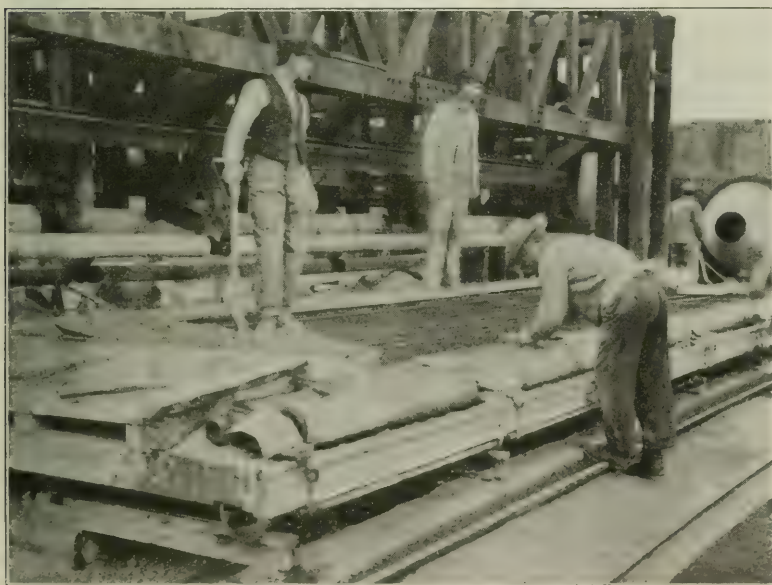


Fig. 5. Rolled Concrete Pile Being Made.

This machine consists essentially of a movable platform, a shaft or mandrel, and means for moving and turning the piles, together with rolls for holding them in line during fabrication. The illustrations, Figs. 4, 5 and 6, show the process quite plainly. Fig. 7 shows the whole plant with some completed piles in the seasoning yard, where the piles are sprinkled frequently to assist the hardening of the concrete.

A somewhat incomplete comparison of the first year's costs of rolled and moulded piling indicates that there is little differ-

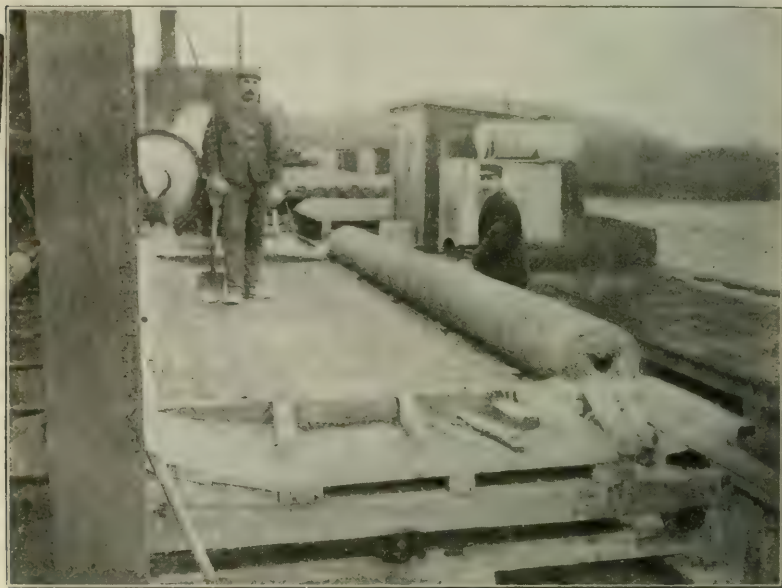


Fig. 6. Rolled Concrete Pile, Nearly Completed.

ence in the cost of the two kinds. As the cost of making reinforcement for the moulded piling was one of the principal items, it was decided to experiment with moulded piling made without taper, the idea being to use a wire fabric, as reinforcement, which could be simply folded into a square and wired together at the lap, thus avoiding considerable labor. The cost of forms is also much reduced if they are not tapered. An efficient plant was designed and is shown in Fig. 8. On each side of each form a rail is placed. A pair of trucks has a short piece of track spiked to it at right angles to the track on which it runs, the level of the latter being such that a car can run off the upper track directly on to the rails between the forms. The car on the trucks is a hopper-bottom dump car and carries a half yard of concrete, Fig. 9. In operation the mixer is placed high enough to dump into this hopper car standing on the trucks. This two-storied car is pushed over to the form and the dump car run off and

dumped directly into the form. In spite of the economy of this arrangement no great difference in the cost has resulted, partly because of the difficulty of handling the square piles. On the



Fig. 7. General View of Plant for Concrete Piles.



Fig. 8. Square Moulded Concrete Piles.

whole, in the absence of definite comparative tests, the writer is inclined to favor the rolled pile. Tests to determine the rela-

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tive strength of the two kinds will be made, however, for both compression and bending. It is probable that each form of pile will be found to have its own place and use.

As yet, no soil has been encountered in which wooden piles could be driven and in which it has not been possible to drive the concrete piles. In some soils it is expedient to employ a jet; in others, an ordinary drop hammer, a steam hammer, or a combination of the jet with one or the other forms of hammer. It is necessary to lift the drop hammer somewhat more slowly for the concrete pile than for the wooden pile, in order not to set the driver into vibration. A cushion of some elastic material must be placed between the hammer and the pile, and with this pre-

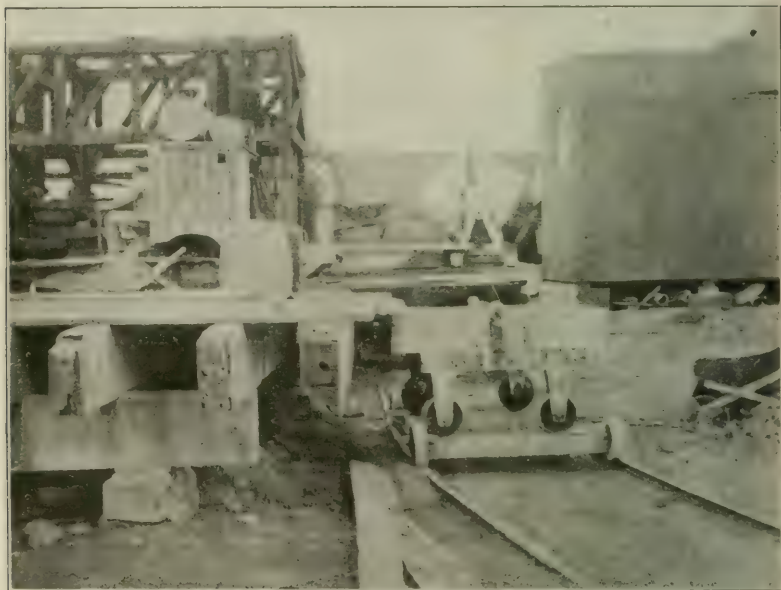


Fig. 9. Hopper Car for Moulded Piles.

caution very little damage to the head of the pile results, even after long continued driving. As a matter of fact, it is surprising how much punishment a well seasoned pile will stand. When it is necessary to drive the pile below the leads, as is generally the case, the follower is placed on top of the cushion. As the loads on these piles are great it is necessary to drive them to refusal, so that accurate knowledge of the required length is necessary. In case it is found that the piles so driven do not reach the elevation called for on the plans, the depth of the cap is increased accordingly. If it is found impossible or impractical to drive the piles to the depth anticipated, they can be cut off without

difficulty. The cut need not be a smooth one, as the casting of the cap will take care of all irregularities of the head of the pile. Should settlement occur in a finished bent, the strength of the cap is important, so that the loads may be equalized and even settlement result. Experience has shown that the design of Fig. 1 provides sufficient strength. Slight settlement has taken place in two bridges but without causing cracks or damage. As the settlement was doubtless due to the fact that the piles had not been driven to refusal, a mass of concrete was placed about each settled bent, extending from just below the ground line to about three feet below; the slabs were jacked up to grade and a layer of concrete was placed between them and the caps. This is shown in Fig. 10.

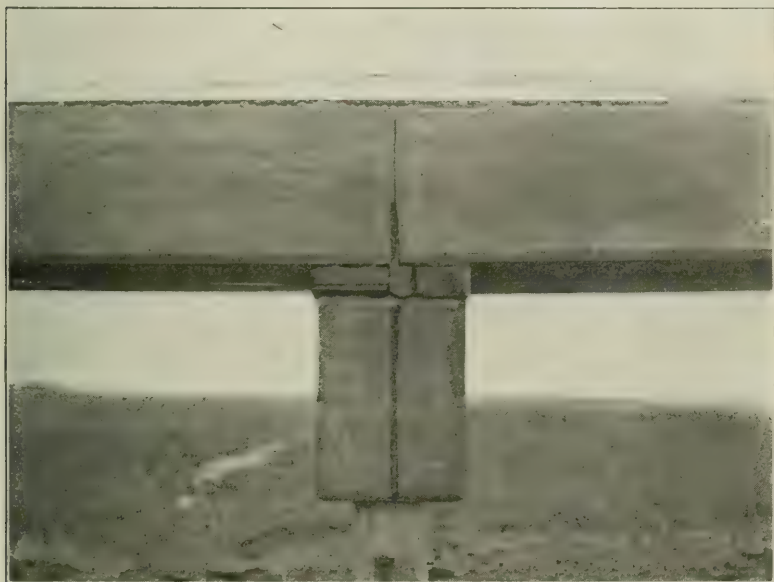


Fig. 10. Concrete Girder, Leveled Up After Settlement.

The manufacture of the floor slabs is best accomplished in a convenient yard, where advantage can be taken of economical methods. Such a plant is shown in the illustrations, Figs. 11 and 12, and in Fig. 13 are shown some of the slabs. It is necessary to provide a firm, unyielding bed. The sides and ends of the forms are removable, and as one span consists of two slabs, a temporary partition is placed in each form to be removed after a half span has been completed. A layer of paper is placed against the slab and the remaining half is cast. Drainage holes are also cast along the dividing line.



Fig. 11. Floor Slabs in Yard.



Fig. 12. Plant for Floor Slabs.

By referring again to Fig 1 it will be seen that U bolts or stirrups are set in the upper part of the slab to permit of its being easily handled. These are set at an angle so that there may be a direct pull when attached to a chain, thus obviating the necessity for a toggle-beam when lifting and placing the slabs.

After the slabs have remained in the forms for from two to four weeks, they are lifted by means of a locomotive crane and piled to one side until hard enough for service, the minimum time for seasoning being three months. When seasoned they are readily erected by the same locomotive crane, a mortar joint being placed between the bottom of the slab and the cap.

After being erected the slabs are painted on top with a

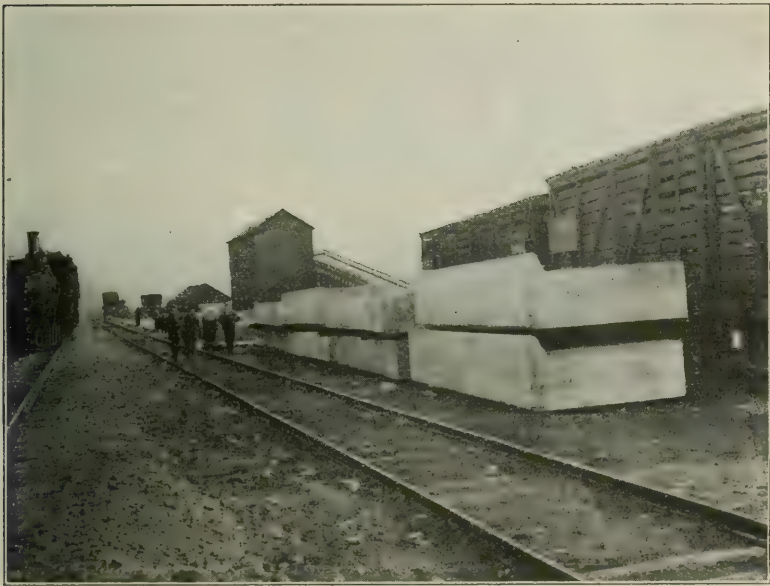


Fig. 13. Concrete Slabs Being Seasoned.

waterproofing compound, and the joints over the caps are filled with a mastic of tar or asphalt and sand. It is better to fill these joints with such material than to allow them to fill with sand, as the former will admit of the slight expansion necessary. Thus far, the best material for waterproofing, with which experiments have been made on work under the direction of the writer, has been found to be a paint made of coal tar, Portland cement and kerosene, after a formula published in an engineering periodical a few years ago. This compound not only covers the surface but sinks into and bonds with it, so that two or three coats are sometimes required. It is put on with paint brushes, in the same

way as ordinary paint is applied. Another valuable attribute is its ability to adhere to moist or even wet concrete. Still another, and not its least recommendation, is its very low cost.

It is evident that in a pile trestle the piling must be capable of transmitting the lateral and longitudinal stresses to the ground, so that considerable bending strength is required.

The double bents are designed to take up such longitudinal stresses as might be apt to place undue bending on the piling. As a matter of fact the stiffness and weight of the floor are such that it is somewhat questionable whether the double bents are necessary. It seems well to put them in, however, as an extra precaution.



Fig. 14. Through Girder, Concrete Trestle on Piers.

As to cost, it is difficult to generalize, as conditions of traffic, length of structure, etc., have a very important bearing. With men experienced in this work, several bridges of lengths of from 80 to 250 feet have been built at a total cost of from \$20 to \$26 per lineal foot, and on lines carrying heavy traffic, while in one or two short bridges of two or three spans, the cost has been as high as \$45 per foot. For the purpose of estimating, a cost of \$30 per lineal foot plus a constant of \$300 will be ample for the design shown.

For bridges having a height above the ground line greater than 16 feet, a plan involving the use of thin piers is preferable.

Photographs of several such structures are shown in Figs. 14 and 15. The piers are heavily reinforced and are generally founded upon wooden piles cut off five or six feet below the ground line. Because of the greater cost of these piers, it is generally economical to make the spans longer than 16 feet, spans of 18 to 25 feet being common. A great number of such bridges have been built and have so far developed no defects. When the spans are as long as 25 feet, however, it is impracticable to build the slabs in a plant away from the bridge, because of their great weight. In general, it has been found best to build them on false work adjoining their final position and to jack them into position.

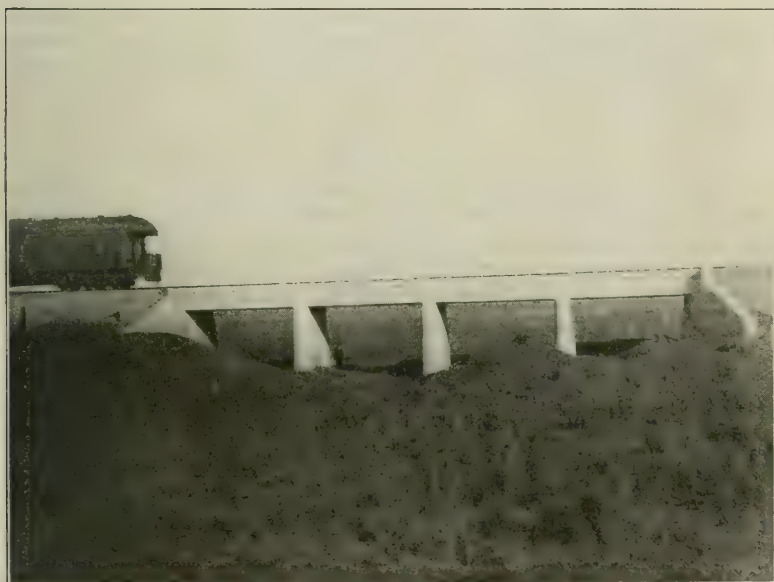


Fig. 15. Concrete Trestle on Piers Over 16 Feet High.

The writer wishes to lay especial stress upon the necessity for the use of the best materials and the most skillful labor on such work. Not only should the cement be tested but also the sand to be used, unless its properties have already been thoroughly established. If the work of making piling or slabs is to be done by contract it should be done by experienced men, under proper specifications and under rigid inspection during every step of the process. If the work is done by company forces, the foreman must be one worthy of confidence, willing to obey instructions to the letter, and intelligent enough to realize the necessity for refinement of the work. The comparative novelty

of reinforced concrete, and especially of such designs, makes necessary a most efficient organization for the work, and the placing of all possible safeguards to insure its integrity. Such organization and safeguards have been in effect in the case of steel construction for so long that they have become matters of course, and when reinforced concrete is carried on with similar care and scrupulous watchfulness, no fear need be felt as to its value as a material of construction. Without these, it is needless to say, it is dangerous.

It is possible, under some specifications, to design short span steel bridges on concrete supports which will be as cheap as the designs described herein, but not, the writer believes, of equal strength to the bridges shown in these designs. Further, if the obvious advantages of ballasted, non-corrodible, fireproof bridges are considered, it will be seen that there is a preponderance of good qualities on the side of the reinforced concrete construction.

#### DISCUSSION.

*Prof. Arthur N. Talbot, M. W. S. E. (by letter):* This novel type of pile-trestle in reinforced concrete designed by Mr. Cartlidge has now been in use on the C., B. & Q. R. R. long enough to warrant the view that it is a durable and satisfactory form of construction, and that it may well be used to replace wooden trestles of low and medium height where the features of short span and adaptation to ground-slope are advantageous, and where conditions will otherwise warrant the expenditure. The erection features are simple and flexible, and the methods of construction permit the structural pieces to be made under the most favorable conditions and to be thoroughly seasoned before being put into service.

The use of concrete piles for this purpose at first seemed to the writer to be somewhat of an experiment. Concrete piles in foundations are usually placed in large groups and are so tied together by the structure itself that the individual responsibility of a single pile is much less than in a trestle. Concrete columns, as frequently constructed, are subject to the criticism of possible variation in quality of concrete in different parts, giving opportunity for local weakness. The objection to poor spots is especially apparent in a column which is to be driven as a pile. It might seem, then, that the concrete pile would be an element of weakness in a structure of this kind. To the writer the existence of weak spots in piles made by the rolling process seemed extremely probable; and as there are others who may still hold this view, he presents the following tests of rolled concrete piles as having a bearing upon the strength and uniformity of this form of fabrication.

The rolled concrete piles were furnished for these tests by the American Concrete Co. They were made at Racine, Wisconsin, December 1, 1908, at the plant which fabricated the piles used in a bridge foundation. The concrete was reported to be one part Universal Portland cement, two parts torpedo sand, and four parts broken stone, size 1-in. and less. The length ranged from 16 to 24 ft. The section was somewhat elliptical but the average diameter was about  $14\frac{1}{2}$  in. The longitudinal reinforcement consisted of five or six  $\frac{1}{2}$ -in. square, twisted, steel bars which were spaced fairly uniformly and just within the light wire netting which surrounded the pile. There were several turns of No. 14 wire at intervals of about 16 in. which were for use in holding the concrete and netting in place after fabrication. It is seen that the steel reinforcement is light and will not give much additional strength. The piles were shipped to the laboratory when about two weeks old.

The piles were fairly straight. Both ends had been constructed square, instead of having a point at one end. As is usual with this fabrication, the irregular space at the end of the pile formed in the rolling process had been filled in with concrete at the time of fabrication.

The tests were made in the 600,000-lb. vertical-screw testing-machine of the University of Illinois. A few hours before loading, the pile was set in place in the testing-machine and the ends were bedded in plaster of paris. The lower end rested on the bed of the testing-machine. The load was transmitted to the top of the pile through a hemispherical bearing-block. The results are given in the table. As might have been expected, failure came generally at the ends where the finishing of the pile by filling concrete into the irregular space between the folds of the wire netting leaves unfavorable conditions for strength. It is evident, then, that the failures at the end are not representative of the full strength of the pile. In the three cases where the failed end was cut off, the second tests (7A, 9A, and 10A) gave materially higher results, and where the second end was cut off (7B) the test showed a still higher value and the pile broke near an end. The pile which broke away from the end (10A, 3 ft. from the top) gave a strength of 2570 lb. per sq. in. One pile, No. 6 (not given in the table), had been broken in three places in handling, but it carried a load of 156,000 lb., and failed by shattering at the bottom of the concrete.

It will be seen that the piles in which the original end had been removed carried high loads, and that there was no indication of lack of uniformity of concrete throughout the length of the piece. In fact, the appearance of the concrete and the action of the piles during test were those of dense and uniform concrete. It would seem that the method of fabricating these under

pressure gives a uniformity which is to be desired. So far as the possible weakness of the ends is concerned, it must be borne in mind that the lower point is in the ground and that with the type of construction described by Mr. Cartlidge the upper end may be cut off, or at any rate is embedded in the concrete cap where it will be protected from lateral failure.

#### COMPRESSION TESTS OF ROLLED CONCRETE PILES.

Spec.	Length, ft., in.	Equivalent Diameter, in.	Area, sq. in.	Maximum Applied Load, lb.	Average Unit Stress, lb. per sq. in.	Age at Test, Months.	Remarks.
1	24 4	14.4	163	280,000	1720	4	Failed along a diagonal plane about 8 ft. from top. Many wires broken and long rods buckled at and near point of failure.
10	24 3	14.1	156	264,000	1690	4½	Failed by shattering at top and bottom.
10A	19 9	14.1	156	401,000	2570	12	This is No. 10 with injured ends cut off. Failed along a diagonal plane about 3 ft. from top.
9	20 7	15.0	177	231,000	1300	4	Shattered at top.
9A	19 3	15.0	177	350,000	1980	12	This is No. 9 with injured top cut off. Failed by shattering at bottom (original end).
2	20 5	15.3	184	260,000	1410	4	Failed at top by bulging and splitting; wires broken at end.
7	20 3	14.4	163	271,000	1660	4	Failed by shattering and splitting at top.
7A	17 0	14.4	163	319,000	1960	4	This is No. 7 with about 3 ft. cut from top. Failed by shattering at bottom.
7B	14 0	14.4	163	356,000	2180	4½	This is No. 7A with about 3 ft. cut from bottom. Failed by splitting near top.
4	20 0	15.0	177	214,000	1210	4½	Failed by shattering and splitting at bottom.
5	16 6	15.0	177	257,000	1450	4	Failed by bulging and splitting at bottom; long cracks extending 18 in. high.
8	16 6	14.8	172	176,000	1020	4	Shattered at bottom.
3	16 0	14.1	156	279,000	1790	4½	Top shattered.

*Mr. C. R. Dart*, M. W. S. E. (by letter) : Relative to concrete piles, the Sanitary District of Chicago, in the spring of 1909, drove 80 Chenoweth piles in abutments of a bridge for the C., M. & St. P. Ry. Co. over the North Shore Channel in Evanston. These piles were 16 in. in diameter and 35 ft. long, reinforced with seven 5/8-in. round corrugated bars. They were made at St. Louis, Mo., and shipped to Chicago from three to five weeks after manufacture. None were injured in loading, during transportation, or in unloading.

These piles were made of extra large diameter, and with more than the usual reinforcement, to resist possible movement

of the abutments. Their large size made the driving very slow, requiring from 600 to 1800 blows per pile from a No. 2 Vulcan steam hammer, with cushion cap, to give a penetration to within about a foot of their tops. The penetration of the pile per blow was imperceptible during the last three or four feet of the driving. The material was clay without boulders.

The piles were driven from 46 to 60 days after manufacture, and notwithstanding the large number of blows received by many of them, not one was injured in any way during the driving. Wooden piles driven at a lower level in adjacent piers were occasionally split under a less number of blows, but of course the driving was done without the use of a cushion cap.

*Mr. E. N. Layfield, M. W. S. E.:* The author says that the 25 ft. spans were too heavy to be put in place by derrick-cars. Was not that the method that was used on the track-elevation work of Chicago for practically the same slabs?

*Mr. Cartlidge:* Yes, but the track-elevation slabs were much lighter and only 7 ft. wide, while the concrete-trestle slabs were 15 ft. wide.

*Mr. Layfield:* Your slabs, then, were for the full width for one track?

*Mr. Cartlidge:* Yes. We have only one derrick-car, with a 40 ft. boom, on the system.

*Mr. T. L. Condron, M. W. S. E.:* In the test-report of Professor Talbot I notice that none of the tests showed a load on the pile in the testing-machine of less than 88 tons, and some of them ran above 125 tons. We are more accustomed to think of loads on the piles in tons than otherwise; therefore it occurred to me that it would be of interest to know what the load is which the piles of these trestles have to carry under maximum traffic conditions.

*Mr. Cartlidge:* Under full ideal load for which the piles are designed, the load is from 20 to 23 tons apiece, the longer spans giving the heavier load.

*Mr. Condron:* The concrete piles are loaded about the same as ordinary wooden piles, and are thoroughly supported laterally by the surrounding earth most of their length. The test piles that failed at their ends, where in actual construction they would be further restrained, carried from four to six times the load which they are called upon to support in actual service.

The criticism of concrete columns as ordinarily made for building-work would not apply to piles cast on the site in forms, nor to these *rolled* piles. All who have had occasion to examine building-columns know that the greatest trouble comes in the proper filling of a long slender shaft from the top. I have recently had occasion to examine some columns which were cast during the winter, and while considerable care was supposed to

have been taken in the casting of these columns, it was found when the forms were removed, that evidently quite a section of ice had formed at the lower ends of the columns, which of course melted later, leaving two or three inches of air-space at the base. It was also found that some of these same columns were frozen, and split from top to bottom as a result. These are conditions that would not occur in the making of a pile, so that it would hardly seem as if these molded piles would have a greater assurance of strength than is found in building-columns, especially columns cast in the winter time. I have been much interested in the description of this rolled pile, which is unique and seems to have a promising future.

*Mr. Oscar E. Strehlow, M. W. S. E.:* The settlement of the bent referred to by Mr. Cartlidge shows to what extent the slab can be shifted about and still remain intact. I recall two instances of even greater settlement. One was a continuous slab built in place across the head race of the Oliver hydro-electric water power, at South Bend, Indiana, 125 ft. long, with bents about 12 ft. from center to center. A washout undermined several of these piers and the bridge settled about 14 in. The slab which settled with the piers was raised with jacks to a proper grade, and there was no indication that there had been any settlement and there was no crack in the slab.

The other case was an arch bridge, with about 70 ft. spans, at Jacksonville, Florida, where the piers were 8 ft. thick at the top. There was a settlement of about a foot in one of the piers, and holes were drilled in the sides and ends of it; plugs and feathers were driven in, and the pier cracked in two; then jacks were installed and the adjacent arches raised to proper grade. This was about four years ago and the jacks are still in place. After every freshet, as the pier settles still more, the jacks are operated and thus the bridge is kept level. The total settlement now is over two feet but it is gradually decreasing; after it ceases, concrete will be placed in the space in the piers, and the bridge will then be safe and complete.

*Mr. Cartlidge:* Since writing this paper, the fact has occurred to me—which it is well to lay stress on—that while this construction has its advantages as a method of construction, it is not a cure-all for the wooden-pile trestle, because the concrete trestle is of such great weight that it cannot be used in very soft and marshy ground, unless there is a subsoil that is capable of sustaining the weight of the bridge. We have found, in our experience, that we have to restrict its use to locations having subsoils containing gravel, stiff clay, or sand, and that black, marshy soil will not carry these trestles safely.

*Mr. I. F. Stern, M. W. S. E.:* The Chicago & Northwestern

Railway Co. had the first installation of concrete piles in the West, I believe.

The plant that was installed in Racine, Wisconsin, was for our company, and the piles that Professor Talbot detailed were made in that plant. The conditions under which we used concrete piles there were slightly different from those for which Mr. Cartlidge has designed his trestles. At Racine we had a 250 ft. draw-span. The old bridge had high masonry abutments, and comparative estimates showed that it would be cheaper to put in piers for flanking spans with small buried abutments in the embankments provided we could get proper foundation in the bank. We decided to use the Chenoweth pile, and let the contract on that basis. We drove the piles there and they gave what we thought was good satisfaction. I have since come to believe that the proper thing to do in a case of that kind is not to use concrete piles but to put in a spread-foundation. I think if conditions similar to that come up again we would not use the concrete piles. We found the same trouble that Professor Talbot noted, that the pile would *broom*—if I may use that expression of a concrete pile—on the ends where it had been filled in, or cast on. I see that Professor Talbot made tests, cutting the ends off, and I have just been informed that this has been done by the Sanitary District, at a cost of \$8.00 for fifteen piles. This certainly shows that the idea is practicable. However, the point of the pile is also cast on to it and I do not think one would want to cut that off. We found, as I said, considerable *brooming*, but, on the whole, the piles did very well. Of course the condition was a bad one and we could not give the piles proper time to season; we had to drive them within about three weeks after they were cast. The manufacture of this style of pile seems to be a very simple operation, and as every step of it is open to absolute visual inspection, one may feel assured that he has a good pile and something entirely different from the case that the Chairman has mentioned, where a long slender shaft is filled with concrete from the top. I think that point has been very well stated.

It occurred to me, in reading Mr. Cartlidge's paper, that there is a likelihood of encountering one difficulty, in driving this kind of pile, that is often found in driving wooden piles; that is, a pile-driver estimates that a pile can be driven to a certain depth, but a boulder is encountered and the pile will project a foot above the track. In the case of a wooden pile, it can be sawed off and if a train comes along it is not delayed for any length of time. With a concrete pile, the case would be quite different. I will ask Mr. Cartlidge if he has ever had such an experience?

*Mr. Cartlidge:* We have that experience quite frequently, but we do not find it so difficult to cut off the concrete piles as has been anticipated. I have had that question asked me a good many times, in correspondence, about concrete piles, and I have always replied that we have no difficulty in cutting them off. With the Chenoweth pile the task is more difficult than with the cast pile because of the presence of the netting, but with two men it does not take to exceed half an hour to cut off a pile. It simply means chipping through the mesh until the bars are reached, and sawing them through—a very short operation; then it is an easy matter to chip off the rest of the concrete. The piles are generally so green—as they are not over a month old when driven—that they have not the strength of a thoroughly seasoned pile, and it is not as difficult a task as might be expected.

*Mr. Stern:* We have not used any of these reinforced-concrete slabs on our road. For a long time we were partial to what we call a T-rail concrete-culvert and the I-beam concrete-culvert, which is in some cases practically a concrete trestle, because we build as many as three or four spans, sometimes up to 20 ft. in length. We depend upon the I-beams for giving strength and encase them in concrete for protection. We do not figure upon the added advantage of the structure as a reinforced-concrete structure, although at a recent meeting of this Society it was pointed out that there was an added element of strength. We like to go up rather high in the unit stresses that we allow in the steel, and if through faulty construction or the effect of moving loads vibration is caused sufficient to dislodge the concrete, the structure will still be absolutely safe and our trains would not be in danger. We are approaching, in fact, the idea of some designers on reinforced-concrete structures of putting in an auxiliary system of steel which is stressed up very close to the elastic limit, although I have not seen many evidences of that system being put in. Of course, with the trestles that we speak of, the I-beam concrete-culverts, and the T-rail concrete-culverts, we may have quite a spread-foundation, so that we can build the trestles on almost any soil, and the objection that Mr. Cartlidge has brought out of not being able to build his concrete trestle on any but gravelly soil is overcome. In Chicago, some years ago, we had occasion to put in a spur track to a manufacturing plant, where we put in a reinforced-concrete structure, and we built practically a concrete trestle, except that we did not use concrete piles, building small piers—rather thin piers—and that is the same thing that we use in the I-beam concrete-culverts referred to. In this case we had about a 13 degree curve, and while the trains operated over that on very low speed, we found no difficulty in maintaining our construction and having the trestle give absolute satisfaction.

*Mr. Condron:* Was that slab reinforced with bars or was it an I-beam bridge?

*Mr. Stern:* There was some bar-reinforcing. We have no objection to putting in bars in places where there are practically quiescent loads. Our objection to bars has been where there are high speed trains and consequent vibration.

*Mr. Condron:* Vibration, you mean, while the slabs are green?

*Mr. Stern:* Unfortunately we have to run our trains over the slabs while they are being put in. Then outside of that, of course there is always the question of water percolation through these slabs. It seems absolutely impossible to get an ideal protection so that water will not drip through, and if we have a construction where we can depend upon our steel, we feel a good deal safer on account of it.

*Mr. Cartridge:* Mr. Stern spoke of the use of spread-foundations in the concrete-pile abutments. Our experience has been somewhat similar,—that it is necessary on a new bank to use a spread-foundation or wooden temporary foundation rather than to put in a permanent foundation. Our practice is now to allow a bank to settle for the life of a wooden pile pier—perhaps twelve or fifteen years—and we find that in general by that time the banks have reached their limit of settlement and we can then put in a concrete pile abutment at very little cost, which will, we suppose, last indefinitely.

With regard to the question of I-beam culverts, we have had some little experience with those. Our first large culverts were built in that manner. Our experience with percolation in concrete and I-beam culverts has been such as to warrant, it seems to us, the use of reinforced-concrete instead. The presence of water heavily charged with rust in streaks parallel to the I-beams, and apparently coinciding with them under deep fills, is quite conclusive evidence that there is some corrosion of the beams, while in our reinforced-concrete culverts with equal span and under equal fills we have no signs whatever of corrosion, although there are some cracks. In our trestles we have no indication of percolation. The waterproofing which we put on seems to be *waterproof*, and the drainage takes away all water pressure.

*Mr. Condron:* As to the structures in which the I-beams have been imbedded in concrete, I think that rust-marks under such structures are very generally observed, showing that water does find its way down between the concrete and the I-beams. That has been very noticeable in a number of the Melan concrete bridges which have been built with riveted trusses in arch form. By looking under those structures it will be found that the steel members in them can be located by the rust-stain on the concrete underneath, and it is quite reasonable to believe

that some water will find its way through such structure in well-defined paths, causing the metal to rust, notwithstanding the protection which the concrete is supposed to give it. The smaller sections of steel in the form of bars are generally more distributed through the concrete, and if bars are placed transversely as well as longitudinally in reinforced-concrete slabs or arches, these will bind the structure together and prevent the formation of lines of cleavage, or cracks longitudinally with the structure. If the cracks cannot form, the steel will be protected.

*Mr. Stern:* We do tie the slabs together laterally by putting in a steel bridging. We use half-inch bars that come in over the top flange of one I-beam, with a hook on that side, and come down under the flange of the next I-beam and then up on to the third I-beam, with the end left plain. These are then forged or heated in the field and bent down over the third I-beam. Then we go from the top of the middle I-beam under the third I-beam, and so on.

*Mr. Condon:* They are x'd between them?

*Mr. Stern:* They are x'd between them to tie them together laterally.

*Mr. Condon:* I should think that to run the bars directly under the I-beams, and, for that matter, other bars over I-beams, the full width, or as much of the width of the structures as possible, imbedding them in the concrete, would be a much more satisfactory method, much less expensive, and give better results. I also think there would be less danger of cracks. The bars would be where they would be most efficient and the cost of the bending and of the forging would be saved. This method, if there is anything in the whole theory of the adhesion of steel and concrete, would give the results that we are after even better than by the bending.

Some years ago I made some rather interesting tests to determine how far a bar would slip in concrete before it would come against a shoulder of the kind mentioned, and found that with imbedment of twelve inches in concrete, even corrugated bars or twisted bars would move enough to break the bond of the concrete, before they would develop a bearing against an adjacent piece of steel, while by imbedding those bars twice that length in the concrete alone the bars could be broken without moving them at all. The occasion of those tests was to try out a form of a mechanical splice for arch bars, and I failed to find any mechanical splice which was at all equal to the mere bond or adhesion of bars in the concrete, although some of those splices were of an expensive type. I think it will be found that by running the bar further along, expending the same amount of money or less, in additional length of bar imbedded in concrete, more positive results will be obtained.

*Mr. Layfield:* Referring to the question of the weakness of the pile at the top, I do not remember whether any of the statements indicated how far that exists, but I notice that in Mr. Cartlidge's drawing the pile is imbedded—I think it is ten inches—at the top.

*Mr. Cartlidge:* A foot, I believe.

*Mr. Layfield:* It seems to me that would very largely overcome any trouble that might be expected to result from weakness of the pile at the top. Of course, the pile is not weakened in the same sense that a wooden pile is weakened when broomed.

*Mr. Condon:* Mr. Cartlidge says the piles are usually imbedded about one foot in the concrete cap.

*Mr. Layfield:* Yes. Wouldn't that provision overcome the difficulty that has been referred to?

*Mr. Condon:* Mr. Cartlidge stated, in reading his paper or describing the pile, that he thought that method would overcome the difficulty.

*A Member:* I want to ask Mr. Cartlidge what his experience has been as to expansion and contraction of the slabs?

*Mr. Cartlidge:* We make provision for expansion and contraction by leaving half an inch between the ends of the adjacent slabs, making each span half an inch short of the length center to center of bents and fill that in with soft mastic.

*A Member:* Has any observation been made as to what the expansion is?

*Mr. Cartlidge:* We find it necessary to make adequate provision for expansion. We found in some cases after setting the slabs in mortar—the weight being very great and the mortar of course setting very hard and with complete adhesion—that the contraction of those slabs in a long trestle would actually pull the concrete apart over the bearing in fine cracks extending longitudinally upward from the bearing toward the center support, or the line through the center of the cap, in a direction contrary to that of shear or tension in the concrete, showing that there was a force there which could only be explained on the hypothesis of contraction. In order to overcome that we now put under our slabs a thin sheet of zinc to which concrete or cement will not adhere. This provides a slippery surface on which the slabs can ride.

*A Member:* Do you put it under every bent?

*Mr. Cartlidge:* Yes, we put it under every bent; both ends of each slab.

*Mr. S. T. Smetters, M. W. S. E.:* I have here the record of the driving of piles by the Sanitary District, under the abutments of the Chicago, Milwaukee & St. Paul Ry. bridge at Central Street in Evanston. The abutments were built high above the water-line, and that is the reason for using the concrete

piles. Forty piles were driven under each abutment. The time for actually driving the piles was from nine minutes—the minimum—to twenty-seven minutes—the maximum. The average number of blows for the minimum was about 600, and for the one that required twenty-seven minutes 1782 blows were required. The minimum time to drive any pile—from one pile until the next one was driven—was twenty-one minutes. The pile driver used was a pair of leaders or guides swung from a stiff-legged derrick. There was an extra line on the boom to handle the pile, the piles weighing, I think, three tons, if I remember right. It requires only a small force of men to do the work, and the concrete piles were handled as rapidly as wooden piles. The maximum number driven in one day was twenty-one, there being no way of getting a higher speed than that, because in part of three days they would drive the entire abutment. After driving about nine piles it was noticed that they commenced to rise, and in that way we found that we would have to cut off a number of piles. That was the reason we had to cut off the fifteen piles Mr. Stern mentioned, at a cost of \$8.00. In cutting off these piles, we commenced with a sledge and battered off the concrete, and we noticed that there were no lines of weakness developed by the driving. One of these piles required 1600 and some odd blows to drive it, and the concrete was solid throughout. We cut off about a foot and a half of this pile. It was not necessary for us to cut off the bars because the concrete was bedded around them, and all we needed to do was to bend them down. The concrete cap that went over the top was so shallow we could not allow the piles to project more than eight or ten inches in the slab. The cost of these piles to the Sanitary District was something like \$37.50 apiece. The price given now is usually \$1.00 per foot for a 14-in. pile, delivered in Chicago.

I would like to ask Mr. Cartlidge where the plant shown in the lantern slide view was located.

*Mr. Cartlidge:* The view showing the machine is that of the Racine plant for the C. & N. W. Ry. Co. The other views are those of the Hannibal plant of the C., B. & Q. R. R. Co. We did not have a view of the complete Hannibal plant but did have one of the Racine plant, so I showed that as a typical plant.

I might say that our practice on the Burlington has been generally to omit the pointing of these rolled piles. We head them in order to provide a hard surface for the hammer. They are driven with tips just as they come from the rolls, with the lower end partly hollowed out, and we have had no difficulty in getting them down.

*Mr. Condon:* The rolled pile has a much rougher surface, of course, than the moulded pile. Of course, if there is anything

in the adhesion of the soil, that would be increased in the rolled pile.

*Mr. Smetters:* I do not think that was the case with those of the Sanitary District.

*Mr. Condron:* Were they smooth?

*Mr. Smetters:* They were painted. We required them to be first class in every respect. I think they took pains with our work.

*Mr. Condron:* That reminds me of a story that one of the bar companies' representatives told. A sample was submitted with a bid for a particular form of reinforcement for a government job and the bid was afterwards accepted. In order that the sample should look artistic to go into the government engineer's office it was painted with dull black paint and the ends were nickel-plated. The contract called for the reinforcement to be up to sample, and when the material arrived the government inspector required that every one of the bars should be painted before allowing them to be put into the work. I do not think, however, that he required the ends to be nickel-plated!

*Mr. A. C. Warren, M. W. S. E.:* In connection with the water-proofing of this work, I wish to inquire if the Portland cement used in connection with kerosene and tar has any cementing or chemical qualities, or if it is used merely as an equally fine ground inert material might be used, more as a body?

*Mr. Cartlidge:* My opinion is nothing but an opinion. I do not know anything about it. The formula for this material was taken from the *Engineering News* and was given to that paper by a naval officer who was stationed at Pensacola and had used this mixture and another one in painting some corrugated sheds which were exposed to the salt spray, and had found this material useful in that way. We adopted it for use on our bridges to protect them against the drippings of brine. Our theory as to the cement is that it is an agency for neutralizing such free acid as exists in the tar and possibly also takes up some water which exists in the tar or kerosene, and which might help to disintegrate the paint if it were left in. As a matter of fact, we have this paint made at a factory which provides us with our standard paint, and sometimes several months elapse before it is used; the cement is then hydrated and in the bottom of the barrel; but it does not seem to affect the quality of the paint, so we have assumed that its purpose was not as a thickener or as a pigment but simply to provide a neutralizing agent. With tar paint it is a common thing to add lime or some other alkali to neutralize the free acid which I believe always exists in commercial tar.

*Mr. Stern:* I should have stated, when I spoke of those I-beam concrete-culverts, that we put in 3-in. No. 16 expanded metal running the entire length of the slab under the beams. I do not think we have seen the phenomenon which has been mentioned of a line

running along showing the crack of the concrete, under any of our structures. In the earlier cases where we did not take proper pains in waterproofing, we occasionally had dripping of water, but I have attributed the sticking or holding up of the concrete to the under side of the pier to the expanded metal as much as to any other one thing.

*Mr. Strehlow:* There is one arch bridge of Melan construction that I think is an exception to those mentioned; that is at South Bend, Indiana, across the St. Joseph river. The exception is probably due to one, two, or three reasons: One is that the Melan ribs were coated with milk grout which would protect them from rust; the second is that there is an excess of sand used, being gravel and sand mixed, just as it came from the pit; the third reason may be the care that I insisted upon in placing the concrete. I have never seen any rust marks under the ribs.

*Mr. Condron:* Did any longitudinal hair-cracks appear?

*Mr. Strehlow:* The bridge has been completed about four years. About a year ago I was going to examine it but the snow was nearly four feet deep and I could not do so; but six months after it was in place I did not notice any longitudinal hair-cracks.

*Mr. Condron:* Were there open lattice arched trusses in that bridge?

*Mr. Strehlow:* Yes.

*Mr. Condron:* And you had bars laterally?

*Mr. Strehlow:* Very light lattice work.

*Mr. Condron:* You also had transverse bars between those trusses?

*Mr. Strehlow:* No; we had very light straps—just a spacing from one rib to the other, about three feet long.

*Mr. Condron:* The subject of proper design or methods of design of reinforced-concrete structures is, of course, a feature of this work as of other work, but I presume that the structures of the Burlington road have been built on the same methods of design referred to in Mr. Tebbett's paper on track-elevation work. It is of interest in this connection, though, to note the fact that at the recent convention of the Maintenance of Way Association a recommended practice was adopted for the design of reinforced-concrete structures. For railroad structures, where impact stresses from moving loads are added to the dead and live load stresses, the allowable unit stress in tension for structural steel bars is 14,000 lb. per sq. in.; for high-carbon steel bars is 17,000 lb. per sq. in.; and for concrete in bending compression, 750 lb. per sq. in. There are a number of other recommendations to which I might call attention, but I think it is important for us to begin to have some recognized unit-stresses for combinations of steel and concrete.

*Mr. Smetters:* Could you use broken stone in making the concrete piles?

*Mr. Cartlidge:* The use of broken stone or gravel is op-

tional, of course, with the engineer. In general it is preferable to use gravel, for the reason that it finds its place more easily and rolls up more readily in the pile. The same is true of the molded pile, but there is no reason why stone cannot be used. As a matter of fact, we do use stone in most of the piles in our work.

*Mr. Smetters:* In the molded pile there is some moisture, but the rolled pile is very dry.

*Mr. Cartridge:* Yes, but we use stone frequently. In Kansas City we are using nothing but stone.

*Mr. Smetters:* Has anyone here had any experience with the Raymond concrete pile molded in place?

*Mr. F. E. Davidson, M. W. S. E.:* In what way?

*Mr. Smetters:* I would like to know what result was obtained after pouring the concrete.

*Mr. Davidson:* The very best result. I would consider the method of driving the Raymond pile as almost an ideal condition. The core being driven in a steel jacket, it is possible to examine the hole before the concrete is poured. Personally I like that method of making a concrete pile, and rather prefer it to the making of a molded pile. That is, however, my own personal opinion. One knows exactly what he has, as he can inspect the hole. There is no chance of breaking off or *brooming*. It is then only a question of properly placing the concrete.

*Mr. Condon:* This is done, as is well known, with columns for buildings, and the hole is inspected—to use the term—but nevertheless almost invariably when the forms are taken off the column, more or less defects are found. If the work has been sufficiently well taken care of the defects are insignificant, but in some cases a block of wood, a lot of sawdust, some dirt, and various other things have gotten down into the column form; that is a matter of serious consideration in concrete columns in buildings, and requires most careful attention. So that even the inspection of the hole may not insure a perfect filling of the form from the top. I am not offering that as a criticism necessarily to the Raymond pile, but am simply calling attention to what I have observed in building-columns.

*Mr. Cartridge:* I am inclined to agree with Mr. Davidson in one regard,—to a certain extent at least,—that the Raymond pile has advantages which no other pile has. It is possible to drive a Raymond pile in situations which will not permit of driving any other pile, and the fact that reinforcement is seldom used in a Raymond pile makes it a much more simple matter to obtain perfect concrete or good concrete than it is in a column in a building or a reinforced column of any sort cast on end. On the other hand, like everything else, no one device is good for all situations, and my idea with regard to the Raymond pile is that some situations, having a very tough and leathery soil,

—such as that on the Evanston channel, for instance,—resulting in the lifting of the pile itself, would be apt to be disastrous to a pile cast in place and seasoned while others are being driven. I have heard of cases in which examination disclosed the fact that the pile had been sundered by the upward pressure of the ground. On the other hand, there are places where nothing but a Raymond pile could be used and a molded pile cannot be driven with any success at any reasonable cost. I believe that each kind of pile has its proper place.

*Mr. Smetters:* I would like to ask Mr. Crocker if he is familiar with the work of driving the piles for the Denver Auditorium. I understand there is great likelihood of encountering boulders in and about Denver. The Raymond people claim an advantage in driving their pile where there are boulders because they have and use the protected shell.

*Mr. H. S. Crocker, M. W. S. E.:* All I know about the Denver Auditorium piles is what little I saw in passing by the work, when in progress. Those piles were driven in gravel and I do not believe any boulders were encountered. The necessity of piling was not great.

*Mr. Smetters:* In other words, you think the foundation was sufficiently good without the piles.

*Mr. Crocker:* They had a very good foundation without piles. Of course, the piles did no harm.

*Mr. Davidson:* I remember a very important building on the North Side where the state of the ground was such that probably the only foundation that could be put in satisfactorily was a system of Raymond piles. A series of test-borings was made which showed that the building site was directly over an old sand-hole,—that is, an old hole where sand had been taken out years ago and the hole had been filled up with rubbish, tin cans, etc., of every description; in fact, as far down as twenty-two feet, rubble stone and boulders were found; almost everything had been dumped in there. The question was, what kind of piling to use there. In taking the matter up with some of my associates I decided that probably the most satisfactory foundation we could put under that particular building was a system of Raymond piles. They drive the shell with a steel core and they assured us that they could drive through anything in that hole.

I agree with Mr. Cartlidge that in a great many cases it is preferable to use some other kind of pile, particularly in soil such as is along the Evanston channel. In that case the Raymond pile should be reinforced, but in building-work in ordinary clay or sand I do not think it is necessary to reinforce the pile itself.

With reference to the waterproofing of reinforced-concrete slabs for railroad bridges, etc., where it is necessary to water-

proof them, has any one had any experience with the use of a waterproofing-compound made of hot pitch and Portland cement,—that is, the cement is added to the pitch when at a temperature of about 250 degrees, and is then applied hot in a plastic condition? I would like to know if anyone has had any experience with that method of waterproofing.

*Mr. Carthidge:* We have not tried Portland cement with hot pitch but we have tried a mixture of fine sand and hot pitch on our track-elevation, without success. The difficulty seemed to be that it could not be made sufficiently elastic to stand cold weather and at the same time of sufficient stiffness to withstand heat and not flow, the result being that at the joints and sometimes in other places there were cracks which allowed the water to go through. Our remedy for that was to put on waterproofing, as has been described, of burlap and asphalt. We find that nothing we have tried, with only one exception, will adhere to concrete except this tar paint. That one exception is a patented article that is on the market at a considerably higher cost.

*Mr. Davidson:* I will state, for the benefit of the meeting, that my authority for the statement that that was a waterproofing-compound was Captain Reed, of Detroit, the president of the Reed Wrecking & Navigation Company. I met the gentleman last week in Buffalo, had a long talk with him, and he told me he was using it and had used it in place of oakum in battening down hatches on a number of lake vessels, and he says the compound is absolutely waterproof; that it is pliable, will not crack, and will stand any kind of usage, and he is my authority that it is absolutely waterproof. I have never tried it personally. He says he uses about one-half Portland cement, mixes it with hot pitch, and applies it when hot.

*Mr. Strehlow:* I would like to ask if those are wood or steel hatches. .

*Mr. Davidson:* Both. He said he used it on both steel and wooden vessels. Captain Reed is an authority on work of that character.

## DIVERSITY FACTOR IN THE DISTRIBUTION OF ELECTRIC LIGHT AND POWER.

H. B. GEAR, M. W. S. E.

*Presented March 23, 1910.*

In the distribution of electricity over a large city for lighting and power purposes, the maximum demand of the day upon the distributing-system varies from day to day during the week, and from month to month during the year. The varying length of the day due to changing seasons, the habits of the population served, and the character of the district—whether residence, mercantile or manufacturing—combine to produce this situation.

In residence districts, for instance, the use of light is such that the maximum demand comes at about 7:00 p. m. in winter and at 8:30 p. m. in mid-summer, as shown in the load-curves in Fig. 1. In outlying business districts in the large cities, and in the central business districts of the smaller cities, the maximum demand comes from 5:30 to 6:00 p. m. in winter, or at 8:30 p. m. in summer. It is usually heavier Saturday than other nights of the week. In the central business districts of cities like Chicago, the maximum demand comes from 5:00 to 5:30 p. m. in winter, and at various other hours in summer. Here the Saturday load is less than that of other days because of the early closing of offices and shops that day. This is also true of manufacturing districts where the load is chiefly power. In a purely manufacturing district, the maximum load occurs at about 10:00 a. m., the afternoon load being from 15% to 20% less than the maximum of the morning. The load-curve in Fig. 2 is that of a power-circuit which carries some lighting and so has a 5:00 p. m. maximum.

In the larger cities the conditions vary in all of these classes of service more or less with the character of the population. The habits of the people in the foreign-populated wards are different from those bordering on the boulevards, and the requirements of dwellers in apartments are different from those living in houses. In the outlying districts of Chicago, stores are closed Wednesday and Friday evenings, while in downtown districts very few stores are open evenings at all and the use of electricity is limited largely to show-window and display lighting. During the summer the loss of demand in residence districts is partially made up by the requirements of the pleasure parks. The combined curve for these various classes of service is shown in Fig. 3.

The combined effect of all these influences is to produce a smaller maximum demand at the generating-station than elsewhere in the system. That is, the sum of the maximum demands of the transformers and distributing-mains is greater than that of the feeder. The sum of the feeder maxima is greater than that of the substation and the sum of the substation maxima is greater than that of the generating-station.

The ratio of the sum of the maxima of the subdivisions of the distributing-system to its actual maximum demand as observed at the point of supply is called the *diversity-factor*. Thus, if the sum of the individual maximum loads on the ten feeders

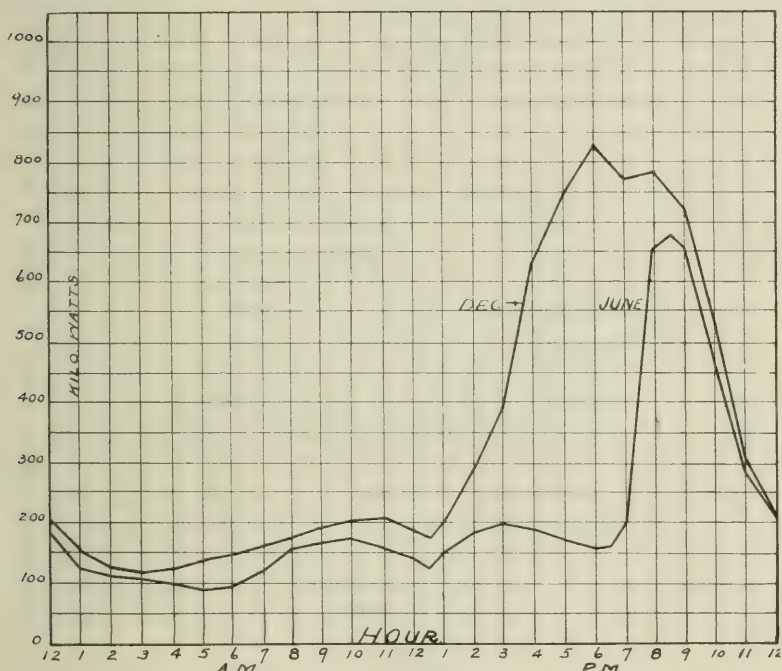


Fig. 1.

of a substation is 1200 kw., and the coincident maximum of the  
 1200  
 feeders is 1000 kw., the diversity-factor is  $\frac{1200}{1000}$  or 1.20.

The study of diversity-factors is of great importance from a commercial point of view as well as being an interesting engineering problem. The investment required by the central station company in the various parts of its operating system for each kilowatt of maximum demand determines the fixed charges which must be considered in determining costs and in making an equitable system of rates.

The existence of a diversity-factor between the demands of a large number of consumers permits the central station company to supply their demands with a much smaller investment in generating-capacity, and at a lower cost of production than would be possible if these consumers were operating individual generating plants. This difference must be sufficient to enable the central station to add the financial burden of a distributing-system and yet have a margin upon which to sell its product economically to its consumers. The effect of the diversity-factor is therefore a subject of interest to both producer and consumer of electricity.

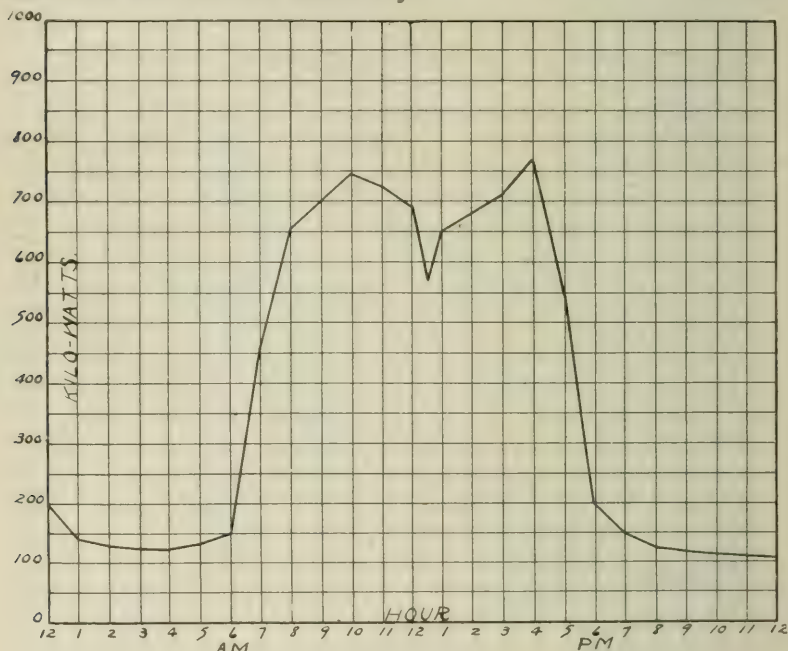


Fig. 2.

The larger the system the greater the diversity-factor, and the study will cover an alternating-current system supplied by substations, feeders, mains, transformers, etc., as shown in Fig. 4. An alternating-current system has been selected for analysis as it is somewhat easier to observe than a direct-current low-tension system because of the presence of transformers whose load may be measured. The loads on the distributing-mains of a low-tension feeder are not so easily measured, and observations, therefore, cannot be readily made.

The consumer being the originator of the demand for electricity, the development of the diversity-factor proceeds logically in the reverse direction from the flow of energy.

Observations made in residence districts supplied by over-

head lines indicate that the sum of the maximum demands of individual consumers is from two and one-half to three times the coincident maximum demand on the transformer, the ratio being lower where there are less than ten consumers on a transformer and higher where there are more than thirty.

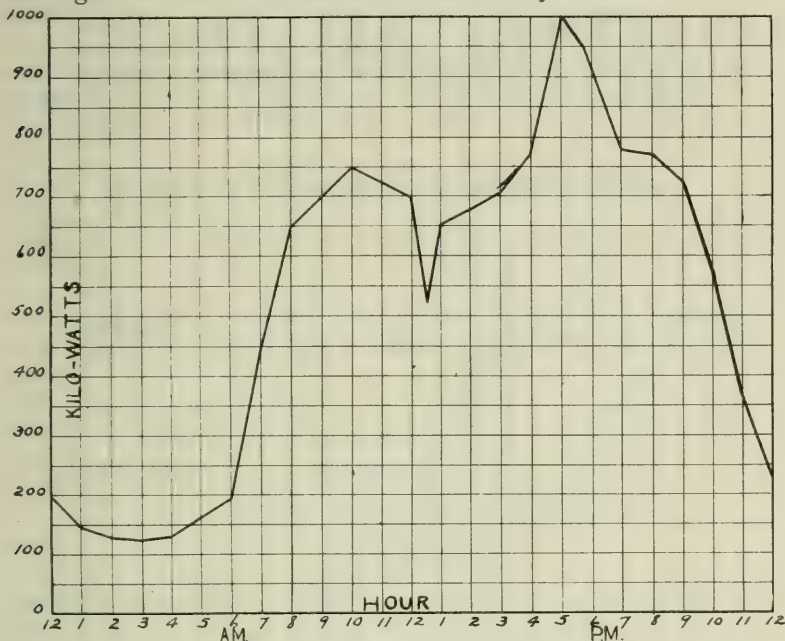


Fig. 3.

In commercial districts with numerous small stores which are supplied by overhead lines, as illustrated in Fig. 5, the coincident demand is much higher in proportion to the consumer's demands.

The ratio of the sum of consumers' maxima to the coincident demand in this class of lighting is found to be from 1.5 to 1.7, it being lower where there is considerable display-lighting, show-windows, etc., and higher where the shops are of such a character that not all the lighting is needed continuously.

In the block of commercial-lighting shown in Fig. 5 there are 55 customers, 26 services, and 1200 lights connected. The measured demand on the transformer at 7:00 p. m. Saturday is 34 kw., while the sum of the readings of the demand-meters

is 55 kw. The diversity-factor is therefore  $\frac{55}{34} = 1.6$ . The

sum of the demand-meter readings is  $\frac{55}{60}$  of the connected-load.

In the densely populated residence block in Fig. 6 the connected-load is 2100 lamps, or 105 kw. The consumers' maximum demands aggregate about 63 kw., and the coincident maximum as measured at the transformer is 18 kw. There are over 175 consumers connected to the transformer. In this case the

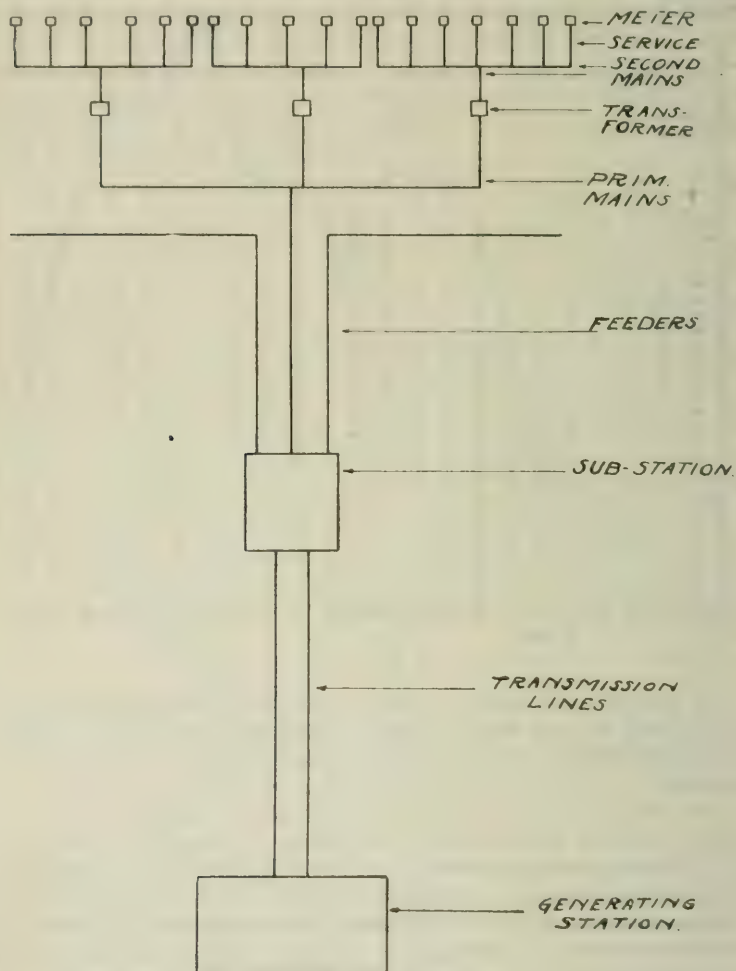


Fig. 1.

diversity-factor is  $\frac{63}{18} = 3.5$  and the consumers' demands are  $\frac{63}{105}$  of the connected-load.

This probably represents as dense a condition as would be

found anywhere in a residence district. It is due in this case to the fact that the block supplied by this transformer consists entirely of three-story apartment buildings, in which about 90% of the tenants are using electric service.

Power consumers are not often grouped so that any considerable number can be supplied from one transformer installation. They must be kept separate from lighting, and therefore usually require a separate set of transformers for each consumer where the load is 2 hp. or more. In large installations advantage is taken of the diversity between meters to reduce the

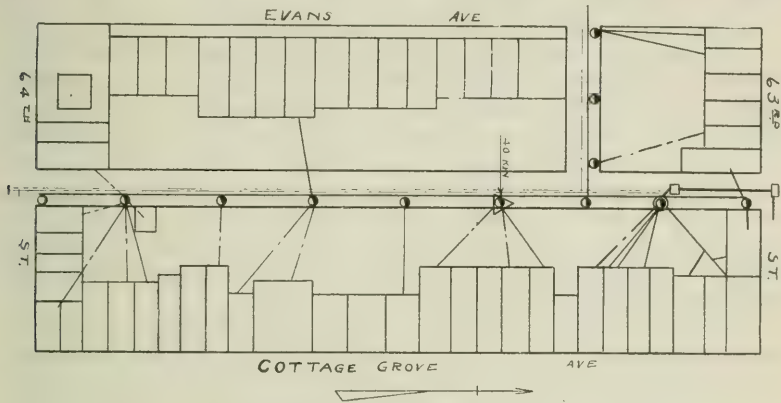


Fig. 5.

transformer-capacity installed. This cannot be done with small consumers except in the occasional situations where several power-consumers are located within a radius of about 500 ft.

The diversity-factor between meter and transformer on power customers is therefore very small and probably does not average over 1.1 for all power installations.

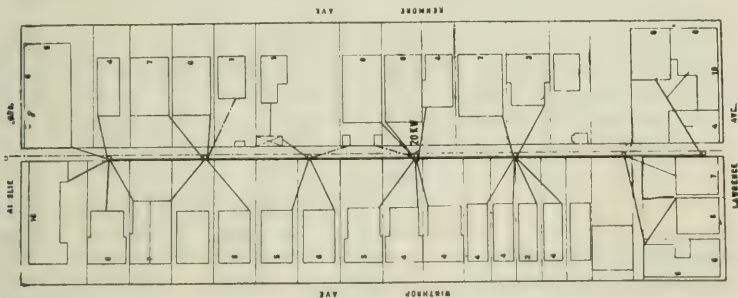


Fig. 6.

Advancing toward the substation, the next point at which diversity may be conveniently observed is at the feeder switch-board. There is a considerable diversity-factor between the sums of the transformer maxima and the maximum feeder-load.

The factor varies with the character of the territory served and with the density of the load. In scattered residence territory, where there are many 1, 2, and 3 kw. transformers, and few larger than 15 kw., the ratio of maximum feeder-load to total transformer capacity is from 45% to 50%. In territory where transformer units vary from 5 to 30 kw., or larger, the ratio is 55% to 65%. In commercial districts with transformers from 5 to 50 kw., the ratio is from 75% to 85% or higher.

Assuming that each transformer carries its rated load at some time during the year, the diversity-factor for a feeder in scattered territory is from 2 to 2.2. In denser territory the factor is 1.6 to 1.8, while in commercial districts it is 1.2 to 1.3.

On circuits carrying a scattered-load power in units of 5 to 100 hp., the ratio of maximum load to transformer-capacity is from 45% to 50%, which makes a diversity-factor of 2 to 2.2. Where a few large power customers, ranging from 100 to 500 hp. or more, are on a separate feeder, the ratio is from 75% to 85%, making a diversity-factor of 1.2 to 1.3. These ratios shift somewhat in a growing system, the tendency being to reduce the diversity-factor as the territory becomes more densely built up. They are also modified somewhat by the losses on feeders and mains, which may be as much as 15% to 20%.

In the substation there is a diversity-factor due to the difference in the character of the load carried by the different feeders. The maxima on the power-feeders occur during the daylight hours, while the maxima on lighting-feeders vary from 5:30 p. m. in commercial-lighting to 7:00 p. m. in residence-lighting.

With three-phase distribution there is a diversity-factor between phases where the lighting is carried single-phase. The net result is that in a substation with ten or more feeders the diversity-factor averages about 1.15. In the substation supplying power-feeders and general lighting it is likely to be as high as 1.2, while in a residence district with little power-load it is about 1.1.

Having thus analyzed the diversity between the various elements of the distributing-system, it is of interest to derive the total diversity-factor from substation to consumer for various classes of business. For convenient reference the following table of diversity-factors will be useful:

TABLE 1.

	Residence.	Commercial Light.	Scattered Power.	Large Users.
Substation to feeders.....	1.15	1.15	1.15	1.15
Feeders to transformers...	1.8	1.25	2.0	1.25
Transformers to meters...	3.0	1.6	1.1	....
Total diversity-factor ...	6.20	2.30	2.53	1.44

From this table it is apparent that the total diversity-factor

for residence lighting is 6.2, for commercial-lighting 2.30, for scattered-power 2.52, and for large users of light or power 1.44. The latter figure would apply to consumers requiring from 100 to 500 kw. The combined diversity-factor of systems giving all of these kinds of service should range from 2.5 to 3.5, depending upon the relative proportion of each kind served.

These factors may be illustrated by a concrete example:

Assume a residence district, well settled, in which the sum of consumers' demands during the heaviest month of the year is 100 kw. The transformer-capacity required to carry the co-

incident demands of these consumers will be  $\frac{100}{3} = 33.3$  kw.

The feeder-capacity required will be  $\frac{33.3}{1.8} = 18.5$  kw. The

substation capacity required will be  $\frac{18.5}{1.15} = 16.0$  kw.

Similarly, the capacity required for a commercial-lighting district in which the sum of the consumers' demands is 100 kw. will be 43.5 kw., for scattered-power it is 39.5 kw., and for large light or power consumers it is 69.5 kw.

This reduction in the amount of capacity required in generating and distributing equipment makes a corresponding reduction in fixed charges which form a large part of the cost of producing electricity. The investment-cost is further reduced by the ability to use large generating-units, which cost less than half as much per kilowatt as the cost of generating-machinery in the sizes commonly used for independent plants.

The merging of all these demands has also a pronounced effect on operating costs, in that the load-factor of the generating-station and distributing-systems is very much higher than that of the consumers who take their supply from it. This permits the station to be run at an economical load a large part of the time, thus reducing both labor and fuel-cost per unit generated.

The combination of these economies constitutes the central station's justification for existence, and it is unnecessary to add that the justification is well nigh complete in these days of steam turbines and 20,000 kw. generating-units.

Thus far the point of view has been from the consumer toward the central station. It is important, however, that the situation be seen from the point of view of the central station toward the consumer, as the diversity-factor has a very marked effect upon the investment accounts which must be carefully considered in determining the cost of rendering the different classes of service.

Stated in the reverse manner for each 100 kw. of substation capacity used to supply residence-lighting, the central station company must provide 620 kw. of meter-capacity, 207 kw. of transformer capacity, and 115 kw. of feeder-capacity. In serving large light or power customers, it must provide 144 kw. capacity in meters and transformers and 115 kw. in feeder-capacity for each 100 kw. of substation capacity.

The diversity-factor for small and scattered consumers is higher than these figures, and these consumers require more equipment and a larger investment than is required for the consumers in thickly-settled districts.

The investment required per kilowatt varies considerably with the type of construction and the geographical situation of points of supply and delivery. It is considerably more for underground lines than for overhead, and no figures can therefore be given which will have great value for other systems than the one to which they apply.

It may be instructive, however, to give some figures to show, in a general way, how the investment is distributed between various parts of the system under a set of assumed conditions which are fairly representative.

Assuming the average cost of a meter at \$10.00, line transformers at \$7.00 to \$10.00 per kw., transformer substations and transmission lines at \$35.00 per kw., and generating-station capacity at \$150.00 per kw., the investment is divided approximately as follows:

	TABLE 2.				
	Scattered Power	Scattered Residence	Dense Residence	Commercial Light	Large Users
Generating capacity .....	37.0%	18.5%	30.0%	44.5%	60.0%
Trans. line and sub-sta.....	9.0%	4.5%	7.5%	10.5%	14.0%
Feeders and mains .....	49.5%	52.0%	26.0%	35.0%	23.0%
Transformers .....	4.0%	4.0%	2.5%	3.0%	3.0%
Meters .....	0.5%	21.0%	34.0%	7.0%	negligible
Total .....	100.0%	100.0%	100.0%	100.0%	100.0%
Investment per kilowatt of annual maximum demand on generating station..	\$410.00	\$820.00	\$500.00	\$350.00	\$250.00

It is apparent from these figures that as far as that part of the cost of electricity-supply which depends upon investment is concerned, small and scattered consumers are the most expensive to serve. This is due chiefly to the large investment in meters and distributing-mains. For instance, the cost of meters in residence lighting is about 25% of \$820.00 or \$205.00 per kw. of station demand. This means that if all the consumers were of this class the company would have as much money invested in meters as in generating-plant.

The commercial lighting and power business, where the diversity-factor is smaller and the consumption demand larger,

requires a less meter-investment and a greater investment in generating and substation capacity.

The maintenance-cost of a large meter and distributing equipment, and the general expense items of meter-reading, billing, etc., are correspondingly high for small consumers, so that it is probable that the outlying parts of the distributing-system are served at a loss during the earlier stages of development.

The study of diversity-factors has not been carried out heretofore in as much detail as is desirable. These deductions are presented as a tentative contribution to a subject which has many angles and must submit to revision as experience and more careful observation may demand, and they should in no wise be considered as the last words on the subject, as parts of them have been necessarily drawn from sources that could not be thoroughly verified. It is believed, however, that, as a whole, they are sufficiently near the facts to form the basis of intelligent discussion.

#### DISCUSSION.

*Mr. W. B. Jackson, M. W. S. E.:* This subject of diversity-factor has been handled by Mr. Gear in an unusually interesting manner. It is difficult to conceive that the realization of the importance of the diversity-factor in the electric-lighting and power business has been of very recent years. Time may be passing more rapidly than I think, but my impression is that only two or three years ago we did not even have a name for diversity-factor, and that the average plant-manager did not realize, in the least, that this diversity-factor of which we have heard this evening was one of the potent factors that made it possible for the central station to compete successfully with the ordinary isolated plant. The fact is that the improved diversity-factor is one of the important elements in favor of the large central station, and it has been a pleasure to hear this question presented so well by the author, because he is engrossed in just such questions as this, and what he tells us regarding diversity-factor is authentic. A broad appreciation of the importance of such problems as have been presented tonight has undoubtedly been an important factor in making the Commonwealth Edison Co. the greatest electric-light and power company—I think I can truly say—in the world. One of the valuable features of Mr. Gear's paper is that his deductions are so drawn that they are of quite general application when appropriately modified to accord with changed conditions.

*Mr. W. L. Abbott, M. W. S. E.:* The question of diversity-factor and its ramifications through the whole subject of carrying as much business as possible with the least equipment is a fundamental and vital one with the designers and operators of

electric lighting central stations. About two-thirds of the expense of operating a central station, counting in fixed charges, administrating and all, is for items which can only be reduced in relative volume by making the equipment carry a greater average load. They are not dependent upon ordinary operating-expenses. Therefore, while the questions of pay-roll, fuel, and other such items are always prominently before us, there are other insidious expenses working with the persistence of interest and taxes which are eating up the earnings of the company unless the equipment can also be made to work day and night. The diversity-factor as applied to residence-lighting, where one householder does not leave his lights burning while he goes to visit a neighbor who has an illumination in honor of his guest, is one feature of this question. The fact that the householder is not at home using his lights, and is not at the factory using his power while he is riding home on the street-car, is another feature, and the more places that the consumer can be touched,—in his home, on the street-car, in the factory or office, in the restaurant at noon, printing his paper at night, and so on,—the greater the profit will be on the investment.

It occasionally happens that while the customer is in his office using light in the latter part of the afternoon when it gets dark early, his family at home are turning on the lights. That is the one time of the year when we cannot split up on the customer and distribute time evenly over the 24 hours. We wish we could, however, and that he would issue a rule at home that no lights should be turned on until he gets there, or until he has put the lights out in his office and finished his street-car ride.

About one-fourth of the generating-station investment is for the purpose of supplying that service during a few hours of the day and a few days of the year when the lights are burning both in the home and in the downtown business-place. The power which we have to generate for this purpose and which is sold for, we will say, 10c per kw. hr., costs the company not less than \$1.00 per kw. hr., and if there was some way of applying the diversity-factor to this character of load,—cutting it off at that time, chucking it into the inverted peak which occurs at noon, using it after midnight, burning it up in the summer-time, using it on Sundays, or even giving it to the competing company, any way to get rid of it from the time and place where it occurs,—there would be a great saving. That, however, is a feature which pursues the central station wherever it is located—in this city or in any other city, in this country or in any other country. They all have that piling up of two classes of load at about five o'clock on the afternoons of long winter days.

I have discovered a way in which we can partially obviate this difficulty, although the method is not yet patented. A de-

gree of longitude at the equator measures about 70 miles; in this latitude a degree of longitude measures about 50 miles; there are four minutes' difference of time for each degree of longitude; therefore for every 50 miles east or west we pass four minutes of time. I propose to establish a station at some convenient place, midway between two large centers of population about 400 miles apart. This will give transmission lines reaching 200 miles each way. By this means I will be able to supply both cities whose lighting-peaks will come half an hour apart, and I will be able to carry about 25% more load on my generating-plant than I could if my customers were all in one city. All that I am looking for now are convenient locations to put two cities and a good place to build the power house.

*Mr. H. Almert, M. W. S. E.:* I do not know where the term diversity-factor originated, but I am inclined to think that it originated with the Commonwealth Edison Co. In that organization I really believe they have the greatest diversity-factor of any organization in the electric-light and power business in the world.

At the Atlantic City meeting of the National Electric Light Association, Mr. Insul, President of the Commonwealth Edison Co., devoted a great deal of time and energy toward the education of the managers of the small central stations. It is really appalling to find what poor diversity-factor and what poor load-factor some of the small central stations have; this might be materially improved by intelligent management.

I had occasion recently to examine some properties in the southwest, where there was a very great diversity-factor as far as classes of service is concerned. In one city there are two municipal water-works, two private water-companies, three electric-light companies, two street-railway companies, one artificial-gas company, one natural-gas company; there they have too good a diversity-factor from the number of sources of service. In that town two of these stations supply seven different classes of electric service, and one of them furnishes five different classes of electric service, each from duplicate lines in the same territory. When one stops to consider the enormous investments of all these companies per kilowatt-demand, Mr. Gear's figures look small. Their investment per kilowatt will run up to something like three times the lefthand column of Mr. Gear's table. They have a combined load-factor of about 9.2%. There is room for a great deal of missionary work in that district.

I think Mr. Gear's paper, if carefully studied and carried into practice, would show increased earnings on public utilities that would have a very beneficial effect on that class of securities, and therefore I think it should have a wide circulation.

*Mr. S. Morgan Bushnell, M. W. S. E.:* The kilowatts shown in the bottom line of Table 2 are not clear to me. Does Mr.

Gear mean kilowatts connected, or kilowatts of maximum demand, or kilowatts of station capacity?

*Mr. Almert:* I would like to have Mr. Gear explain how that maximum is determined,—whether it is a momentary maximum, or a momentary maximum for the year?

*Prof. P. B. Woodworth, M. W. S. E.:* In Table 2, as shown, I suppose the figures in the top line are based on a constant value of generating capacity, since it appears that the 30% of \$500.00 in the column headed "dense residence" is the same as 60% of \$250.00 in the column headed "large users." I do not quite understand why there is such a difference between the cost of transformers for scattered residence distribution and large users. The cost of transformers for scattered users is about \$16.00 per kw., while for large users it is \$7.50 per kw.

*Mr. A. Bement, M. W. S. E.:* Two things occur to me. One is that electrical people are very scientific in their business,—much more so than people in other occupations. There is probably no business of any size or character in which conditions are so fully analyzed as they are in the electrical business; this, I think, has done a great deal in putting the electrical business where it is, and a lack of analysis of the essentials in many other lines of business accounts for their less successful development.

Electrical people are prompt to invent terms by which they may express their meanings and convey their ideas to others, and thus be able to make each other understand what is being talked about. Lack of proper terms often causes confusion in stating a problem and conveying to others the meaning desired, with the result that people beat about the bush and say things that are taken to mean something else. The invention of the terms or expressions that come along so promptly and frequently in the electrical business is of great assistance to the prompt solution and the ready realization of ideas as they develop.

*Mr. G. H. Lukcs, M. W. S. E. (Chairman):* Mr. Gear has shown in the left-hand column the total investment per kilowatt for scattered residence districts, and he has explained that in the fringe around a large city, and in the city itself, business often has to be carried at a loss. As one gets further out, the problem of operating the company with financial success becomes exceedingly difficult, and that explains why there must necessarily be a difference in rates. I presume that the figure of \$820.00 per kw. would go up as one goes out from the center of the city. Necessarily, as the diversity-factor cannot be greatly improved, the rates for that class of business must be higher,—must be kept above city rates.

*Mr. F. F. Fowle:* One of the things that occurs to me as notable is the system of rates which has brought about the large diversity of demand which Mr. Gear has so clearly shown, and

which, broadly speaking, is a sliding-scale system of charges based upon the theory of charging in proportion to the quantity used. This contrasts with the early days when the flat-rate system was in vogue, and it is notable that there has been a very recent tendency in some cases to go back to a flat-rate system of charging in connection with Tungsten lighting. But it seems to me that this diversity of demand has made possible the very great commercial development now enjoyed, because of the fact that so many different kinds of business can be taken care of, particularly in the residence sections, over a given set of feeders and transformers. If that were not so—if no such diversity-factor were present—we would find it impossible, probably, to give service at the present rates or at rates anywhere nearly as low. If we should go back to any extent to a general flat-rate system, it seems to me it would have a very profound effect upon the diversity-factor, and in turn upon rates.

I recall some figures from an electric property in a city of about 16,000 population. It had a connected-load of approximately 1400 kw., and the maximum winter-peak was about 600 kw. The summer-peak I think ran considerably less than 400. I was interested in Mr. Gear's remark, too, that diversity-factors probably are not the same in any two properties. In the city of which I speak there was a notable difference in the daily peak—the instantaneous peak—from day to day in any one week. That city had a very large industrial development, and it was notable that the stores were open on the evening of pay-day; there was always a very large load on that day; in fact, it was generally observed that the highest peaks in the week came on the evenings when the stores were open. In those cases it was quite notable that the power-load, which was considerable, produced a very high winter-peak because it overlapped the lighting-load. Those loads became separated in point of time or coincidence in the summer and resulted in a much lower peak.

#### CLOSURE.

*Mr. Gear:* The generator-capacity was figured at \$150.00 per kw., and the substation capacity at \$55.00 per kw. straight through. The other figures—feeders and mains—were made in a more or less approximate way, and for any particular case would have to be figured out individually. The term **large user** refers to customers of 300 to 500 kw.; in fact, those particular figures were made up for a 300 kw. customer with 100 kw. units, which cost about \$7.50 per kw. On the scattered power a little higher cost per unit of transformer-capacity would apply,—that is, somewhere about \$8.00 to \$10.00 per kw.,—because it would be in smaller units; but there is a larger diversity-factor between the transformers and the feeders in scattered power, which makes the amount of transformer-capacity for a given

amount of feeder-load twice as much for that class of business as it is for large users; so that for 5 kw. of feeder-load it takes 10 kw. of transformer-capacity, whereas with the large user the transformer-capacity need be only 25% more. The cost per kilowatt of station-load is therefore higher for the scattered-power load.

The same explanation applies to the meter-cost. The cost of the meter is about \$10.00 for a 5-ampere meter having 0.55 kw. capacity, and about \$20.00 per kw. if it carries its full load, but when the diversity-factor is applied, it runs up to 34% of \$500.00, or \$150.00 to \$160.00 per kw. That explains the high cost of equipment where the diversity-factor is large.

It might be of interest for you to know that in the outlying districts of Chicago the Commonwealth Edison Company's investment in meters alone is over \$100.00 per kw. of station-demand, so that these figures are not merely theoretical,—they have been actually realized.

In regard to the difference of diversities in different plants or different properties, that is one of the reasons why it is difficult to draw final conclusions which are generally applicable to every property. Chicago is such a large city that we have illustrations of that fact right within our own city. The requirements of the West Side are entirely different from those of the residence district on the North Side, and the requirements of the South Side are still different, so that the diversity-factors in those sections of the city are different. The proportion of power and commercial-lighting on the West Side is high as compared with the residence-lighting, while on the South Side it is very low compared with the residence-load. On the North Side there is considerable power in the district south of Fullerton Avenue, and a very heavy residence-load north of Diversey Boulevard. On this account it has been possible to get a good deal of information about different classes of load.

The kilowatts shown in the bottom line in Table 2—referred to by Mr. Bushnell—are the maximum kilowatts at the generating-station. That is, for each kilowatt of maximum demand on the generating-station, the investment for the entire system would be \$820.00, as shown at the foot of the second column.

On a mixed lighting and power system—as in any large generating-system—the load comes up and goes down gradually. The actual maximum usually lasts at least ten minutes, and momentary swings are not considered.

## DEPRECIATION AND RESERVE FUNDS OF ELECTRICAL PROPERTIES.

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WILLIAM B. JACKSON, M. W. S. E.

*Presented at a joint meeting, W. S. E. and A. I. E. E.,  
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Every company operating an electric light and power property, a street railway property, or a telephone property, or contemplating entering into any such field of activity, must take into account certain expenses that cannot be appropriately included in the day by day operating and office costs or in the current maintenance expenses of the property, if its accounts are to show in full the actual cost of performing the services required.

I refer to the sums of money that must be set aside to cover depreciation replacements and to provide a reserve fund to care for extraordinary costs as hereafter explained.

The term *depreciation* as here used may be divided into two parts:

1. *Decrepitude*—Which covers the gradual wearing out of the apparatus from the effects of use and of age, which cannot be overcome by current repairs, and which results eventually in ending the operative life of the apparatus.

2. *Obsolescence*—Which takes into account the reduction in the useful life of apparatus, on account of advances in the art whereby otherwise operative apparatus is made uneconomical for further use.

The term *reserve fund*, as here used, may also be divided into two parts:

1. *Required Reconstruction*—Which takes into account reconstruction costs made necessary by municipal or other legislative requirements.

2. *Special Insurance*—To cover expenses that cannot be forecast with any degree of certainty, caused by extraordinary occurrences such as unusual storms, explosions, great conflagrations, acts of strikers, etc.

In considering *depreciation* it is well to clearly separate in one's mind the annual depreciation of the plant as an average whole and that of the component parts making up the plant. To obtain the true amount of the annual depreciation in the value of any property, it is necessary to estimate a sum of money which represents the yearly depreciation of each of the component parts of the plant, and the aggregate of these sums of money for all parts of the installation gives the annual depreciation for the plant. This may be converted into a percentage

on the total value of the installation which is subject to depreciation. Any method of arriving at the amount of annual depreciation that does not take into account the individual depreciations of the component parts of a plant, must be an approximation at best, even though it may be based upon results obtained in a correct manner for other similar plants, and it may be very far from accurate.

This division of a plant into its component parts for purposes of determining its annual depreciation is usually a simple matter. It requires that each of the component parts shall be such that when it has reached the end of its useful life the part in its entirety will be discarded, and that it shall be possible to intelligently determine its probable salvage value as a whole. If these requirements are not fulfilled the part should be divided until they are.

If we consider the overhead distribution lines of an alternating current electric light plant, the lines may be divided into the following parts: bare wire, weatherproof wire, rubber covered wire, transformers, lightning arresters, insulators, and poles and cross arms with their hardware; and in some cases there may be further divisions. The poles and cross arms with their hardware can usually be considered together as one part, as cross arms and hardware generally outlast the poles but seldom are used again when their corresponding poles are discarded, so that a pole and its fittings may be considered as having useful lives of equal length. It will be seen how impossible it would be to determine a fair amount for the depreciation of poles and wires without thus analyzing the aggregate, owing to the widely differing useful lives of the two kinds of plants and the great difference in the proportions of their salvage values. Or again, consider electric railway track; there are the ties with short life and no salvage; there are the rails with medium life and good salvage; there are the frogs and switches with short life and low salvage; and there is the electrical bonding which may be considered as having the same life as the rails and to have medium salvage. It would be impossible to determine a fair annual depreciation for track considering all of these parts together, but it is possible to obtain the fair average depreciation by taking the aggregate of the amounts found by considering the several parts individually.

The total amount of depreciation to be annually charged against any part of the installation should be equal to the first cost of the part installed ready for service plus the cost of removal, less any salvage obtainable for the part when discarded, divided by the years of probable life of the part.

The estimation of what is the fair useful life for any part of a plant presupposes a thorough knowledge of the nature of the service demanded of the part, a broad acquaintance with the

general experience respecting like kinds of plant, a studied survey of the probable effect of local conditions upon the useful life, and a keen knowledge of the past and present progress of the art for the purpose of making an intelligent forecast of the rate of depreciation caused by approaching obsolescence. A fair determination of the useful life is thus based upon several independent variables, and the result must be reached by judgment after duly applying what seems to be due weight to each of the factors involved.

In estimating the fair salvage value to be assigned to any part of an installation, it is often possible to fix it by some relation to the actual junk value of the materials comprising the part. For instance, the salvage value of a lead-covered paper insulated cable that has finished its useful life will be substantially the residue of the junk value of the lead melted off, and of the copper with the paper burned off after the cost of withdrawing the cable from its place of service and preparing the junk has been deducted, though sometimes cable rejected for use in one kind of service may be used in another, in which case its value when discarded from its original use may be the value of cable that would ordinarily be used in the second service, assuming good engineering judgment in the construction and operation of the property. The matter is not so simple with buildings and machinery. With the former it will frequently be found that the cost of removal will equal the junk value, and the salvage value is therefore zero; while with the latter the price that can probably be obtained from a second-hand dealer for the machinery in place may sometimes be considered as the salvage value, and in other cases the salvage value is the price that can be obtained from an old metal or junk dealer for the machinery in place.

The factor of obsolescence entering into the question of useful life of plant, whether of buildings, machinery, or other plant, is a disturbing one. This has the effect of reducing the estimated useful life of many parts of most plants below that which would be indicated by the ravages of decrepitude, and it likewise affects the probable salvage. Where the factor of obsolescence is estimated as likely to terminate the useful life of a part before decrepitude would be likely to cause its rejection, the former factor must determine the useful life. Consequently, the factor of obsolescence may be the determining factor in fixing the length of the useful life of some parts of a plant, and decrepitude may be the determining factor in fixing the length of useful life of other parts. In other cases these two factors may jointly influence the length of life. The factor of obsolescence has been an exceedingly important one in the several kinds of properties under consideration, and especially so in connection with all kinds of switchboards and other controlling apparatus. But its effect is very apparent, even when considering what we think

of as the most stable parts of an electric generating plant, though revolutionary effects are not so apparent today as they have been in the past. Let us consider a large high grade engine-generator set for alternating currents. Few of us would be willing to place at less than fifty years the period during which such a machine should be physically capable of doing, under good care and management, the particular work for which it was designed; but no conservative engineer would allow, when estimating depreciation, that such a machine will have, in ordinary commercial electric service, a useful life of fifty years, because advances of the art would inevitably affect its usefulness. In consideration of the great changes that have taken place in the past in apparatus for the generation and distribution of electric power, and the probable changes that will take place in the future, such a piece of apparatus cannot appropriately be allowed an estimated useful life of over twenty to thirty years. Local conditions also may influence to a considerable degree the length of the useful life that may be allowed.

Most public service companies are forced to make large expenditures by ordinances of municipalities or by other legislative action. These are required changes, such as changes from overhead construction to underground construction, relocation of distribution lines on account of new street surveys, changes from wooden poles to iron or steel poles, changes in track construction owing to paving of streets, etc. The costs of such changes up to the value of the original construction should not be made an addition on capital investment and they cannot appropriately be considered as a part of current maintenance, but they should be provided for by a *required reconstruction* fund. An adequate estimate of a suitable yearly contribution, on account of required reconstruction, can only be accomplished after a careful study of what expenditures have been made in the past on account of required changes in the plant under consideration, accompanied by a study of the district served by the plant with the view of forming a judgment of what requirements are likely to be imposed in the future. In the case of changes from overhead to underground line construction that are likely to be required, it is sometimes possible to make quite definite estimates of the cost of such changes for many years to come by a study of the character and probable rate of development of the territory covered by the company's lines, from which an estimate can be made as to what will normally become underground territory year by year. And in some cases a regular schedule of such changes is determined by city ordinances.

The question of what annual charge should be made on account of *special insurance* is also difficult to solve with exactness, but it is one of which sight should not be lost. The ordinary maintenance expenses should not be expected to include such costs as those occasioned by the destruction of a power

house roof by a wind storm, the annihilation of a boiler-room by a boiler explosion, the razing of a pole line by sleet and storm, etc. It is, therefore, appropriate that an annual amount be laid aside for each part of the plant, except, of course, land, to create a fund to remedy such damages which come once in a while to every plant. The element of chance must enter very largely here, but chance is not such a fickle factor in operations when its effects are distributed amongst many parts of a plant.

These factors of *required reconstruction* and of *special insurance*, which I have considered under the heading *reserve fund*, are quite different in their characteristics from depreciation, but a plant will just as surely get into the breakers if its reserve fund, or some equivalent to meet these expenses, is not kept in good shape as when no provision is made to take care of depreciation.

If replacements are taken care of by capital account, a property becomes burdened by an imaginary capital investment in physical property which is almost sure to be a serious handicap when the company desires to reduce rates or make improvements. Where replacements are permitted to be taken care of by capital account, the capital account becomes something like the wallpaper in a room (to use a homely comparison) which has been put on layer upon layer, the old not having been removed when the room is newly papered. The papering is not worth more than the last effective layer, and in fact the lower layers sometimes prove the destruction of the whole, and so it may be with an inflated capital account.

By capitalizing replacement costs, the burden of carrying these costs is thrown upon the future without limit of time in cases of unlimited franchises, when this burden should have been borne by the past, except during the period in which a company is still in process of building up its business to a remunerative one.

Most plant managers have not yet come to a full appreciation of the dire straits a plant must come to sooner or later if the depreciation appropriations or their equivalent are not systematically and intelligently attended to. We may consider, for example, a property having a large investment in pole lines. This may amount to as much as 10 per cent of the value of the plant. For the first ten years comparatively few replacements of poles will be required, but during the next two years most of the poles may have to be replaced. Thus an average amount of money equal to almost 5 per cent of the plant investment may need to be expended each of these years for pole replacements alone, and other parts of the plant are surely and irrevocably coming to the same condition. Thus, if there has not been due regard given to a depreciation fund, or the plant is not extraordinarily prosperous, great difficulty will be encountered in obtaining the necessary money for replacements when their need begins to be acutely felt.

A third division is sometimes made in depreciation, called *inadequacy*. This factor covers costs which are occasioned by the necessity of discarding otherwise serviceable plants on account of growth of business. For example, if an electric plant is operating with three small dynamos, and it is found necessary to increase its capacity, it may be best to displace one small dynamo by a larger one, even though the small dynamo may be far short of having operated during its entire useful life, estimated from the standpoint of depreciation. The fund accumulated on account of depreciation for this dynamo, plus the salvage, would likely not cover the loss occasioned by discarding the apparatus at that time. This difference might be made up by a contribution to the depreciation fund on account of inadequacy. This factor should be of small importance in a plant planned and operated with excellent engineering judgment, and it is so closely allied to obsolescence that it does not seem necessary to add a third division to depreciation. It may be properly considered as a part of obsolescence wherever it enters as an appreciable factor in any consideration of depreciation.

The expenses that are considered in the foregoing pages are as real as the pay-roll and other daily operating expenses of a plant, but the ravages of depreciation frequently do not show to a noticeable degree until several years after the beginning of the operation of a plant, and there are also likely to be long periods during which it is unnecessary to make much, if any, outlay on account of required reconstruction and special insurance. For these reasons there is serious danger of overlooking the importance of these expenses in promoting a new enterprise, or in the early days of the operation of a public service company. But if the earnings of a company, after it has become well settled in its business, are not sufficient to cover a fair appropriation annually to the depreciation and reserve funds, as well as to cover the regular operating expenses and a reasonable return on the investment, that company is one that conservative investors should shun. If the conservatively estimated earnings of a new project do not show that they will provide such returns, it should not be considered an attractive project.

Having considered the general question of depreciation and reserve funds, let us now consider how the principles involved should be applied.

Few kinds of apparatus depreciate in value by equal yearly increments, but nevertheless the final effect of decrepitude or obsolescence is to eventually wipe out of the true assets of the company the value of the part less the amount saved by salvage. Such being the case, it will be readily seen that as a piece of apparatus having a useful life of  $n$  years, for example, will be in service just  $n$  years, each year of service will reduce its serviceableness to the owner one  $n$ th part. Its depreciation should,

therefore, be based upon equal yearly increments of one  $n$ th, in determining the annual contribution that should be made toward the depreciation fund.

Therefore an annual contribution to the depreciation fund should be made such that in  $n$  years it will accumulate an amount equal to the first cost of the part installed ready for service minus the net salvage, net salvage being defined as the junk value less the cost of removing the part and preparing it for sale, that is, as the net sum recovered. But the annual contributions should draw interest at the usual trust rate for the state in which the plant is located, and the annual contribution to the depreciation account is, therefore, less than one  $n$ th of the first cost of the part. Thus, if the trust rate is 4% and  $n$  is 10 years, the actual percentage of the cost that need be set aside annually would be 8.33% of the first value of the part minus estimated net salvage. In this way the annual contribution to the depreciation fund for each part, or group of parts having the same useful life, may be determined, taking into due account the differences in life and salvage of different parts, and the sum of these several amounts gives the annual contribution to the depreciation fund for the entire plant. With this amount known, the proportion which the annual contribution to the depreciation fund has to the total cost of the plant subject to depreciation is at once available, and the percentage of annual depreciation is known.

This statement may be qualified to a certain extent by the fact that every plant will take some time to obtain a paying business, and that during this period of upbuilding it is not expected that the earnings should cover a depreciation fund. Such being the case the annual appropriation to the depreciation fund would be omitted during this period (which should not be long) and correspondingly increased for the later years of operation.

In case of reconstruction and special insurance, the average annual amount of expenditure that is likely to occur must be determined as closely as possible in the manner already described, but here no trust interest can be considered, for, while at times the fund may show an accumulation, at other times it may be negative, so that interest received at times of accumulation may be considered as offsetting interest paid during times of borrowing.

The accumulation of these funds is for specific purposes and the money should be used only for those purposes. Also, those purposes should be supported solely from these funds. Thus, when property must be replaced on account of its depreciation, the cost of doing this (less salvage on the discarded plant) should be defrayed out of the depreciation fund, and when an underground line must be substituted for a useful overhead pole line, on account of municipal legislation, only the difference

between the first costs of the underground and overhead lines should become a capital charge, and the remainder of the expenditure (less salvage) should come from the accumulated funds. It is obvious that the depreciation fund will accumulate in the earlier years after a plant has been established, because the replacements during the earlier years will be few; but after a plant is fifteen or twenty years old, the expenditures for replacements and the contributions to the funds will somewhat nearly balance when averaged over several year intervals. In all but the very largest and most comprehensive plants, the expenditures for replacements and required reconstruction will vary greatly from year to year, but the amount contributed to the fund each year should follow the computed average figure; and the sum maintained in the funds may therefore vary.

Sometimes depreciation funds are put into new plant instead of into accumulated funds. There is some question as to the advisability of this. Unless the books of a company are kept with extraordinary care, or the plant represented by the depreciation fund is kept distinct from the remainder, it is difficult to keep track of what plant represents capital investment and what represents depreciation. This difficulty is magnified, as the plant representing depreciation itself depreciates, thus introducing an additional factor that must be taken care of in the bookkeeping, and eventually the concern is likely to lose the enviable situation of having its books show the actual facts regarding its property.

It may be said that an old plant worked down to its ultimate operating condition will have an annual expenditure for replacements which remains approximately uniform, so why permit the depreciation fund to lie as a trust fund when it might be actively used in additional plant? If the depreciation fund is put into plant, the company is likely to lose its ability to show the relation of its physical property to its capital investment, and it cannot then show a true relation between earnings and the physical value of its plant. The fact cannot be ignored that the people of this country today expect public service companies to be in a position to show that their service is satisfactory and supplied at a reasonable cost, and it, therefore, seems necessary that such companies should be able to know their actual investment in property which represents capital invested.

The coming of public service commissions, having power to regulate the rates of public service companies, has raised the question whether the depreciation of a plant should have an influence upon the earning power of the company. It seems patent that a company should be permitted to earn a fair return on a full, reasonable, unimpaired capitalization regardless of depreciation, so long as it supplies equally good service. This question would not seem to me to be open to doubt were it not sometimes a subject of serious discussion, and were it not that

some respected publicists seem to hold that the net earning power of a public service company should be less after its plant has been subject to depreciation than when brand new, even if it gives equally good service and the stockholders have received back no part of their invested principal, but only fair returns in interest.

With a properly conducted property the fact that the property has suffered depreciation, which is unavoidable in any electric plant, should not have the effect of injuring the quality of its service or of impairing its capital, which would be the case if its recognized earning capacity were expected to decline proportionally with the increase of its depreciation fund.

If a fair figure has been estimated for the annual contribution to the depreciation fund, this fund will always carry sufficient money to make replacements when required, and as the income from the depreciation fund is used to help build the fund, the owners of the property will not receive returns on their money twice. The investment in the property does not diminish as the plant depreciates, and I do not understand that any one claims that an amount equal to the depreciation may appropriately be distributed to the security holders of the company and thereby reduce the capital outlay in physical property. If the security holders are permitted to receive interest and dividends based upon a fair return on the investment in their property during the first years of its operation, I am unable to see how this basis may be fairly changed during later years, so far as investment is concerned, after the plant has depreciated, as the investment has remained unchanged.

There is another phase of depreciation I would like to touch upon before closing.

The tendency of today is to make sweeping changes in plant and methods, to permit of less expensive or of improved service. On this account many excellent plants in good operating condition are shut down and the requisite power received from other sources. A company cannot well charge off of its capital account the value of such plants which may be comparatively new when they are put out of commission. In fact I have in mind a plant of 1,000 kw. capacity, which is of modern design with steam turbine-generators not over two years old, which with several other plants is being shut down owing to the possibility of obtaining power from another source at less cost than it can be produced in these plants. The question is, what should be done regarding the capital value of such plants? Unless it is necessary to retain the plants in reserve, I believe they should be dismantled and the capital of the company reduced by the amount received from the sale of discarded machinery and other property. Then the difference between the amount received from their sale and their actual capital value to the company may still be continued as a true asset of the company, and that

value be gradually charged off at the normal depreciation rate of the plants discarded, the capital of the company being reduced each year by actual liquidation of that amount. In other words, the situation is one wherein the regular depreciation appropriation is made on account of the property until the full cost of the discarded property is returned to the security holders. After this no further appropriation should be made on account of depreciation of the property concerned, as no replacements would have been made on the property, and consequently it would have been depreciated out of existence. The economies derivable from abandoning the discarded machinery should be sufficient to extinguish in this way the capital value of the abandoned plants, or else the transaction is not an advisable one.

In conclusion I will say that, where electrical properties have been failures in the past, a goodly proportion of the failures may be traced to lack of provision for depreciation expenses and for extraordinary expenses. The reserve fund, besides covering such extraordinary expenses as are mentioned in the foregoing discussion, must be sufficient to care for losses occasioned by any recession of income which may come in the train of the physical results of the extraordinary occurrences discussed. The proper organization of a depreciation fund in conjunction with the reserve fund will also fortify a company against difficulties on account of reduced net earnings during lean years, which every company must expect, and which lean years will be offset by good years.

All of you will appreciate that it is impossible to figure the expenses considered in the foregoing to a high degree of exactness; but they may be figured logically and intelligently, and it may be said that a company which follows the principles here laid down regarding depreciation and reserve funds is likely to travel along an untroubled path so long as its field of operations provides sufficient earnings to warrant the company's existence.

#### DISCUSSION.

*Mr. J. G. Wray, M. W. S. E. (Chairman):* We are greatly indebted to Mr. Jackson for this very interesting and instructive paper. The public, many publicists of note, and, indeed, the managers of some of our public service corporations and of other corporations, have failed in the past and even today fail to realize the importance of this subject. The subject of depreciation has been driven home to public service corporations, particularly during the last few years, because of the interest taken in the operation of the public service concerns by the public, by state commissions, and by municipal authorities. The idea of piling up a large fund, which in a big public service corporation may run up into the millions, strikes one who has not made a study of this subject as merely another way of getting an undue amount of money from the public.

The management of corporations, and in particular of public service corporations, has perforce to be done on a more scientific basis than in the past. The treatment of depreciation, as I say, is a subject of the last three or four years with most companies, and in fact of even more recent consideration by many of them. I have in mind that the president of one of the oldest and largest public service corporations said not many weeks ago that a depreciation fund was quite unnecessary, as the maintenance account served to take care of both upkeep and replacement.

I am sure there are a great many here with experience who will disagree with that gentleman.

*Mr. C. N. Duffy*, Comptroller, Milwaukee Electric Railway and Light Co.: I am a little embarrassed, talking before all these engineers, because I am not one of them. I am nothing but an S. C. A. (a So-Called Accountant). This is my apology for talking on depreciation. However, the chairman has made some reference to the Milwaukee Company, and without taking too much of your time, I will state that in 1896 the city of Milwaukee sought, by an action in the courts, to reduce the fare from five cents to four cents. The case came up before Judge Seaman in the United States District Court. The cost of the property was proved to be \$8,885,000, tangible and intangible. Mr. William J. Clark, of the General Electric Company, made an inventory and presented it in evidence, showing that the physical cost of the \$8,885,000 was \$5,200,000. The remainder of the cost sum was the *buying* of the situation. This may be digressing from depreciation, but it is of interest in our case in Milwaukee. The \$5,200,000 invested in physical value was of no value without the buying of the situation; the situation was of no value without the investment of the \$5,200,000 in the property. The situation bought was the buying of several properties and merging them into one, and although in many instances they represented only a franchise and two streaks of rust, they had to be bought and the person that was selling had the naming of the price. In the case referred to, as may be familiar to some of you, the language of Judge Seaman in making the decision was that it was quite clear to his mind that there had been at least \$7,000,000 in cash put into the property; that there had been at least \$5,000,000 of that \$7,000,000 put into physical property, and that on the testimony of witness Beggs (Mr. Beggs at that time was associated with the company only in an advisory capacity; he afterwards became and is now its president and general manager) it was very clear to his mind that if depreciation had been recognized and provided for in the accounts of the company, the annual return on the investment would be too small to permit of any thought of reducing the fare. In 1906, exactly ten years afterwards, we were met with another issue. The city of Milwaukee sought to reduce the fare from four cents to three cents. I might say, in passing, that subsequent to 1896 (in 1899) there was an ordinance passed giving the

company the right to operate for thirty-five (35) years, from January 2, 1900, on condition that we would make a four-cent ticket fare, twenty-five tickets for a dollar, or six tickets for a quarter. In 1906, notwithstanding this ordinance, which was a plain contract between the City and the Company, the City sought to reduce the fare from four to three cents. We took up the question of the defense of the case on the lines of this paper, as to depreciation, and I want to give expression here to the value of many of the points which Mr. Jackson has brought out in his paper, one of them in particular, that a depreciated property does not represent a diminished investment. There was a physical examination of the property by the Wisconsin Railroad Commission. I believe that Professor Pence has enlightened this Society as to how it was made. The books of the company for ten years were examined for the City by Barrow, Wade, Guthrie & Co., and upon that evidence they sought to proceed against our company in the matter of the reduction of the fare. The case was tried before the Railroad Commission of Wisconsin. (Tried is hardly the proper word, hearing I should have said). We had a hearing before the Railroad Commission of Wisconsin which occupied some seven or eight weeks, and our contention was that the \$5,200,000 of physical property which had been proved in 1896 in the courts should be taken as being worth at least 80% of new cost; 80% represented about the proportion of the existing value to the cost new as made for the entire property as of December 31, 1906, by Professor Pence. We took this value as \$4,000,000, and to that we added only the cost of physical property without any discount on bonds, without any promoter's profit, without any interest during construction, and with absolutely nothing of an intangible nature. It was the cost of the physical property as produced under work orders in our own organization. This cost made a sum in round numbers of \$14,000,000. The position we took was that we were entitled, after operating expenses, taxes, and depreciation had been taken care of, to a fair return on that \$14,000,000. We did not stand on our legal rights. We did not claim anything for intangible investment or overhead charges or bond discount. We took this as a basis, feeling that it would be better to take the minimum basis and then go up, if necessary, rather than to start high and drop down. This physical property in round numbers was valued on the basis of existing conditions by Professor Pence and his staff at \$7,000,000. Mr. Beggs, president and general manager of our company, beginning January 1, 1897, arbitrarily appropriated out of the earnings of the company—without any thought of the lives of the different classes of property, the type of the apparatus, their use or anything of that kind, or the investment in any sinking fund—10% of the earnings as a depreciation fund to take care of extraordinary replacements and renewals, as distinct from current ordinary replacements and renewals which were charged into operating expenses as maintenance. Now, from Janu-

ary 1, 1897, taking the value of the physical property at \$4,000,000, plus in round numbers about \$10,000,000 added physical property, in ten years about \$7,000,000 of that property had disappeared, according to the valuation of Professor Pence, which valuation none of us ever questioned. We had every confidence in Professor Pence's honesty and ability. What does this mean, or what did it mean? It meant that the company had sustained a loss, not taken on its books, in round numbers of \$3,600,000. It meant that the 10% of the gross earnings set aside was only equivalent to about half of the amount that should have been set aside.

I make this statement, partly in response to the statement of your chairman, that there are some people who claim that a depreciation fund is not required. I have heard this debated in meetings of the American Street & Interurban Railway Association. I have heard managers of some of the largest properties in this country assert that the maintenance took care of depreciation, so that there was no depreciation. But that has not been our experience. We do not want to argue the case. It is unnecessary to argue it. Consider the facts.

Now with regard to what Mr. Jackson said, that he was giving expression to his own ideas in a general way as to what constituted the main questions regarding depreciation. I think that he is to be congratulated that he has presented a paper along those lines. There are some points which do not quite appeal to me as practical propositions. For instance, this question of building up the depreciation fund on the sinking fund plan. Now as I understand Mr. Jackson, he wants to give expression to the necessity of recognizing the figuring of depreciation on that basis, but does not intend to give the impression that it is absolutely necessary to invest money in a sinking fund in order to accomplish the results which he says must be, and which we know have to be, accomplished. What I mean is this. I do not believe, as a practical question, that an electric property, be it railway or lighting, can absolutely set aside, year by year, the exact amount proportionately and invest it, in order to work out the depreciation fund on the assumed basis of the interest increment being added to the amounts set aside. There are many reasons why that cannot be done. In the first place, there is the question of lean years, particularly when the property first begins operations; the first five years more than likely will show deficits rather than surpluses. Then comes the question whether or not the money can be invested—assuming that it has been set aside—and that it can be invested in a sinking fund that will yield the amount required and that the withdrawals from the fund will be in proportion to the way it has been built up.

To illustrate, take the Chicago City Railway Co., or the Chicago Railways Co., on the North and West Sides. Assume that the Board of Supervising Engineers, after careful investigation and consideration of all the factors, determines that the life of a given

number of cars—100 cars, for instance—would be (we will say for the purpose of illustration) twenty years. That does not mean that all of the cars will last twenty years. It means some of them will last more and some of them less. Now, then, one must have a flexible fund or he must have his fund in such shape that if it is necessary to replace some of those cars at the end of the fifteenth or the sixteenth or the seventeenth year, or if they run over to the twenty-fifth year, he can take care of them. That is the practical question.

As a matter of fact, The Milwaukee Electric Railway and Light Co. has not an invested depreciation fund. The company built up a fire insurance fund, an injuries and damages fund, and a security deposit fund; these three funds are invested funds and the interest on the investments are added to the funds.

It seems to me that any one who wants to figure out what his depreciation will be must of necessity follow the plan laid down so well by Mr. Jackson in his paper with regard to giving recognition to the interest increment on the depreciation fund. If it is not invested and is used in the business as working-capital, or if it is used for extensions, or whatever may be done with it, it seems to me, as far as true results are concerned, as far as correct accounting is concerned, in the question of rates and service, so far as the relation of the company to the public is concerned, the public must be given the benefit of the increment of that interest. It does not make any difference whether it is invested in a so-called sinking fund or trust fund or not. But there are ways of taking care of this proposition. As a matter of fact during the first five years of the life of an ordinary property one may not set aside a quarter or a half of what would be the annual apportioned amount. That is why it seems to me that the straight-line basis rather than the sinking-fund basis is the preferable as well as the more practical one. In the second five years 50% or 75% of the annual apportioned amounts might be set aside, and in the next ten years one may make up what was lost in the earlier years. There is nothing to prevent this as far as the accounts are concerned. To meet the gentleman who says that interest on the money is being obtained twice, the depreciation fund can be credited with the interest and can be deducted from the income, or in taking the depreciation charge on the books, give credit for the interest against the increasing charge for depreciation in the particular year being dealt with. This has been our position in the hearing before the Railroad Commission in the matter of the three-cent fare.

I might say, in passing, that the most recent and I think the most important decision rendered by the Wisconsin Railroad Commission was given out March 8th, relative to the rates of the Madison Gas & Electric Co. In that decision, among things that are highly important to all of us, even to those of us who are not engineers, the Commission intimates that money is worth 6% as

the cost of the money, and that in a gas property there should be a profit over and above this 6% of  $1\frac{1}{2}\%$  to 2%, and in the electric-light business of 2% to  $2\frac{1}{2}\%$ , and that that profit must be attained after everything has been taken care of, including depreciation and, as I take it, also casualties and several things alluded to by Mr. Jackson. In their summing up of the case and in their decision as to the rates which they reduced,—or rather, adjusted, they were reduced in some instances but it is more generally an adjustment, as I understand it,—they gave the life of an electric light plant on the average (and I think I ought to correct myself there, because I understand from Mr. Jackson that it ought to be, not the life of the plant, but the average depreciation of the plant that should be considered) at about eighteen years, and of a gas-plant about thirty years. They recite the features of the installment plan for the depreciation reserve fund as compared with the sinking fund plan, and they state that at least a 2% sinking fund must be taken into account for the gas, but nothing for the electric plant.

*Mr. Wray:* I would like to note, in passing, a reference to one of the points Mr. Duffy makes,—the advantage of a straight-line depreciation over a sinking-fund depreciation,—an advantage which would seem to be necessary in the case of a public service corporation that, like the telephone company, is required, or may be required at a certain period to sell out to the city at its depreciated value. The point is a very important one when we recall that the sinking-fund curve is concave to the base. In other words, one does not accumulate an amount which will equal the investment until the end of the life of the plant—the theoretical life of the plant upon which the depreciation figure is based.

*Mr. George Weston, M. W. S. E.:* The subject of depreciation has become one of interest to engineers and operators of public utility properties, brought about principally by municipal ownership agitation and the activities of federal, state, and municipal governments in the regulation of rates, fares, and capital securities, requiring a *present value* for properties under consideration.

In addition, the importance of depreciation in its relation to the finances of a company has made its study necessary in order to provide for the payments of renewals out of the earnings of the property.

The paper presented here this evening by Mr. Jackson sets forth, in considerable detail, methods for predetermining depreciation of physical property, which briefly consists of determining a cost new and the salvage value for each component part of the property, the difference between the cost new and the salvage equaling the value of the depreciable part. In order to ascertain the average annual depreciation for each component, the wearing or useful life must be predetermined; these calculations are necessary in order to determine the *present value* of any property or to determine an an-

nual depreciation fund to be set aside to take care of the renewal of each component part at the end of its useful life. The first cost, the salvage value, and the useful life of each component part are questions of fact and can be quite accurately predetermined or estimated, and if the earnings of the properties will permit, it is practicable to establish a reserve fund to take care of renewals.

Mr. Jackson, in his analysis of depreciation, has referred to *obsolescence*, extraordinary expenditures due to changes required by municipal ordinances, etc., and also refers to *special insurance* to cover loss due to destruction of property by wind-storms, explosions, or other extraordinary causes, and recommends that reserve funds be established out of the earnings of the property to provide for these extraordinary expenses. Obsolescence and inadequacy of plant and equipment will occur to a greater or less degree in the property of any public-utility or large manufacturing plant. Loss of property is liable to result from extraordinary causes, and public-utility companies, operating under governmental or municipal franchises or ordinances, may be required to make changes in their plants or equipment on account of its obsolescence, inadequacy, aesthetic or other seemingly necessary reasons. However, all of these extraordinary losses are very difficult to predetermine, and therefore should not be included in the factors to be considered in predetermining the rate of depreciation of property, for use as a basis for establishing annual appropriations to reserve funds.

Factors used in determining depreciation for reserve funds should be confined to those necessary to determine the *wearing value* and the *normal wearing life*. Wearing value is the difference between the cost new and the salvage or scrap value. The normal wearing life is the average length of time in years during which the particular class of cars, buildings, engines, generators, or other property considered, will be serviceable, it being understood that the proper *maintenance repairs* will be made from time to time.

The normal wearing life should not be affected by obsolescence, extraordinary changes, extraordinary accidents, etc., for in case supersedence takes place before the end of normal wearing life, then such proportion of the cost of the new article that has accrued to date in the *renewal fund* to the credit of the article superseded should be paid out of such renewal fund, and the balance of the cost could go to Capital Account, or preferably this balance should be carried as a floating debt to be retired by surplus earnings in the future.

As a question of finance, the establishment of reserve funds, to be maintained out of the earnings of the property, depends upon the relation that the gross income bears to the operating expenses and the fixed charges. The gross income should be such that in addition to meeting operating expenses, depreciation, and fixed charges upon the actual investment, the property should earn a fair

return to its operators for skill, hazard, etc., but if the property does not show sufficient earnings to properly take care of all of these, then payments should be made preferably in the following order:

1. Operating expenses.
2. Fixed charges.
3. Depreciation.
4. Dividends.

There are different ways of maintaining reserves to cover depreciation, such as a specific cash fund—or, as it might be termed, a *surplus*—and if a specific fund is desired, a basis for determining the amount to be paid into the fund monthly or annually must be found. This should be such as to provide in the fund, as nearly as practicable, cash (or its equivalent) equal to the amount of depreciation at any time during the normal wearing life of the depreciable part of the property or at the end of the period. There are two general methods used to determine the amount of this periodical payment into a fund; one is called a *straight-line depreciation* basis, which divides the total wearing value into a number of parts equaling the normal wearing life, and these amounts are paid into a fund periodically to maintain the fund without reference to interest; the other method is termed a *sinking-fund curve* basis, referred to by Mr. Jackson, and involves the payment into a fund periodically of certain specific amounts bearing interest at a predetermined rate compounded, which will, at the end of the period of normal wearing life, equal the wearing value, or the payments could be changed in amounts at each period so that together, with the interest compounded, the fund will at any time equal the amount of the depreciation. Mr. Duffy, in his remarks, questioned the practical features of a sinking-fund curve basis, on the ground that he did not believe the rate of interest that could be realized from a sinking fund could be predetermined. I believe it is practical to work out a plan so that a corporation can invest its sinking fund in its own securities, and that by so doing an annual rate of interest can be very closely predetermined. This, however, as stated above, is a financial problem and no hard and fast rules can be laid down covering depreciation; each property, being a problem by itself, must be treated as conditions direct unless the earnings can be made to fluctuate at will. In that event, fixed rules or factors can be determined and the earnings regulated to fit the case.

In the past many public-utility properties have been managed by persons who spent as little money as possible for repairs, made no provisions whatever to provide for depreciation out of the earnings, but paid fixed charges and high dividends, thereby placing a fictitious value upon the stock, capitalizing renewals, and in some instances operating expenses as well. Usually, after setting full sail and heading the ship towards financial rocks, these pirates would sell out and leave the other fellow and the small stockholder to endure the losses. These methods of juggling public-service properties

have given the public false impressions about profits in the business, and are largely responsible for the general agitation against public-service corporations in the past. The present operators of such properties should adopt a systematic method of counteracting these erroneous ideas by applying, in the operation of their properties, correct financial principles based upon making the properties a commercial success.

*Mr. Wray:* The point in Mr. Weston's remarks that depreciation is largely a financial question, referred to by Mr. Duffy, it seems to me is very true. A public service corporation during its earlier life, when perhaps its earnings are not enough to more than pay dividends, and when the demands for new capital to take care of extensions are very great, has got to be able to dispose of its securities to advantage; otherwise it will fail. Naturally it should not be required at that time to set aside money in a depreciation fund. It is very essential to keep up its net earnings and to keep up its dividends, so that its securities, its stock, and perhaps its bonds, can be disposed of to advantage, and extensions provided for. The depreciation fund can wait and be taken care of during the fat years.

*Mr. C. N. Ubelacker* (of Ford, Bacon & Davis, New York): On the short notice with which I was favored this evening, I can not attempt to make any suitable discussion of Mr. Jackson's very able paper, as it is a large subject. I simply want to present to you a few points that have been questions in my mind on the matter of depreciation and on which I cannot say that I have as yet clearly made up my own mind.

In the first place, the question of how we are going to handle depreciation depends largely on the purpose to which we are going to apply our depreciated value. Are we figuring depreciation for the purpose of making a rate? Are we figuring to know where we are going to come out in our financial arrangements? Or are we simply going along adding some certain per cent. of our gross income to a surplus each year, with the hope that it is going to make good any difficulty that we get into in the future? If we are figuring depreciation for the purpose of making a rate—for the purpose of allowing an amount in addition to operating expenses and fixed charges which must go to make up the expense of giving the service—then we have to consider the term during which the service is going to be given, during which we have a right to give the service or a right to expect that we will be allowed to continue to give the service at the rates fixed. In other words, is our franchise or our charter an unlimited one so that the only question we have to meet is our ability to turn out 100% of service from the apparatus and plant which we have, or is our charter and franchise a limited one, at the termination of which, as your chairman drew attention to, frequently it is necessary to give up the property for its selling value?

In the case of a limited term franchise, of course we must take into account that during the term in which we have the right to give the service we have to provide a depreciation fund sufficient to meet the difference between the original investment and the sum for which we can dispose of the property, but I cannot see that it is anybody's business but the stockholders' whether we give them from time to time certain surplus earnings which eventually will have to come out of their pockets, due to difference in the selling value and the first cost of this property, or whether we pile it up in a fund and eventually return to them the whole of their first investment. Why should we make quite such a strong point of depreciation as long as we realize it is going on, and what we are coming up to in the end and do not try to deceive people and make them believe they are buying 100 cents on the dollar, when they are really buying only 90 cents?

There is another question that has some influence on the way we are going to figure on depreciation. That is, what view are we going to take of the service we are giving? Are we renting service, renting the use of a plant, or are we selling the product? If we are renting the use of a plant, it is the business custom that the plant shall be considered at 100% of its new value as long as it will turn out 100% of service. If you pick up a hackman along the street you do not ask him whether his horse is six years old or nine years old. If it will take you to the station in ten minutes you will pay him just the same in either case. If we are giving the service, we are entitled to 100% of our new value as long as the plant will turn out 100% of service. That being the case, why should we charge supersession on the plant that is still turning out 100% of service? Why should we make elaborate provision for meeting supersession after a definite period when we do not know what that period is going to be? Supersession is a very uncertain thing and not subject to accurate prediction.

Depreciation due to wear and tear Mr. Jackson calls decrepitude. I have always preferred to call it deferred maintenance, because it is really maintenance. We might as well have one term as two.

Supersession, as stated above, is a very uncertain thing to figure out, and to my mind it does not take place until the article is actually taken out of place and superseded by another. It has been very rapid in the past, but the experience in the past, which is the only thing we have to go by, is of little help to us. Supersession takes place less and less rapidly as the art grows older. In other words, our curve of supersession becomes eventually asymptotic. I think some of you will remember an account in a recent *Cassier's* of the third locomotive Stephenson built. It has been in operation ever since (over 80 years) and is still in service. There have probably been a great many repairs and there are not many of the old pieces in it, but supersession has not taken place. So why build up a big

fund for supersession, when we do not know when it will occur? Let us go back to the principle that the new apparatus which goes in will earn sufficiently more money, or will operate sufficiently more economically, so that the difference in the receipts or in the expense between that and the piece of apparatus which has been superseded will take care, in its term of use, of the cost of what we have discarded or the working value of the superseded apparatus. Why not let the man that gets the benefit of the improved service of the new apparatus pay for it? Why should we load on to the rate or on to the cost of service from the original apparatus the cost of what is eventually going to be improved service in the future? The man that ought to carry this expense is the man that gets the improved service, and for that reason why not look upon supersession as being taken care of out of the increased economy of the superseding apparatus? These are questions concerning which I have not yet decided myself, and I would like to see if I can get any light on them tonight.

*Mr. E. J. Fowler* (Statistician, Commonwealth Edison Co.): I suppose that among the electric-lighting companies there are about as many different methods of keeping track of depreciation as there are different kinds of rates. There are a great many companies, of course, that do practically nothing along this line, and there are not many that go into the subject very thoroughly as yet, but to my mind they will all have to go into it more and more in the future. It seems to me that the subject is a very timely one. The question of depreciation is one that may not be as serious to electric-lighting companies as a great many may imagine, when the appreciation of land value, the interest-increment of the fund, the salvage value, and the very long life of some classes of investments are considered. The average rate of depreciation is probably not as large as a great many have considered it in the past, or as large as a great many figure it at present. There are probably a great many concerns who are taking care of depreciation in the shape of different kinds of funds, reserves, surplus, and so on, probably amply taking care of it, although they have no really good system for doing so. It seems to me it is much better to have a system, and the state commissions, or other authorities, will undoubtedly require more and more carefully prepared systems and more uniform systems. I think, as some of the other gentlemen have said, that where the property is thoroughly well maintained, where liberal charges are made for maintenance, practically the only depreciation that is serious is the one that Mr. Jackson calls obsolescence. Decrepitude is in a great many cases undoubtedly taken care of in the regular maintenance charges.

*Mr. Harold Almert*, M. W. S. E.: It is really refreshing to hear a paper of this nature discussed before a body which it is generally supposed is purely technical and pays no attention to the financial end of projects after they are completed. Many engineers plan for

ample capacity and reliability of service without regard to first and ultimate cost, leaving to the commercial end the keeping down the cost to the proper limit.

The speakers this evening I think have all spoken from the standpoint of the large properties. There is another class, the small fellows, who have not the technical staffs to study out these problems and who have been working in the dark and are still so working on this subject of maintenance and depreciation and they are unknowingly doing themselves, their stockholders, and their bondholders a great injustice from lack of knowledge of this subject. The average central-station manager, I think, is to be criticized somewhat for his lack of effort in upholding rates in the past few years. It is really alarming to see the rate of decrease in charges for electric service in the past ten years, and especially when we note the enormous increase in the cost of labor, supplies, and machinery—in fact, the cost of everything else, including the cost of living. There has been a very decided increase in the cost of everything else except public-utility service, which has been going down at an alarming rate.

One speaker called attention to the fact that it is not necessary to consider supersession until the time comes, and I am reminded of the condition of the electrical industry some ten or fifteen years ago, and of a cartoon in *Puck* or *Judge*, or some such paper. A man going home late in the evening, shortly before Easter, a little the worse for wear, had a large box in his hand. He met a man coming in the opposite direction and they endeavored to pass each other, when the one with the box finally said, "For goodness' sake, don't stop me. Let me get home with this bonnet to my wife before it gets out of style."

While the condition of the electric industry was not exactly the same at that time, improvements in apparatus, due to advance of the art in the past fifteen years, came so quickly that it was not very far from the same situation as the man with his wife's hat. In fact, not more than five or six years ago, while visiting a big station in New York City, I saw them erecting the last one of eight or nine large reciprocating-engine units for which the station was designed, and at the same time that they were erecting this eighth (or ninth) unit they were taking out the first one to make room for a turbo-generator which had superseded it. As I stated before, there are a number of owners of public utilities who are principally interested in other lines and have not given proper study to this subject of depreciation, and who are unknowingly doing themselves and their stock and bond holders a serious injustice.

I have just come from the examination of a set of books on a property which wishes to issue some additional bonds, and in this particular case the fact is the plant investment account *on the books* is in the neighborhood of \$5,000,000. Our engineers who made the

physical valuation of the property finished their work the week previous and had given the property every consideration possible, having added the proper amounts for engineering, interest during construction, legal expense, and those various other items which are right and proper. They could not show an inventory to exceed \$1,200,000 as a valuation of the physical property today. On examination of the details of that account and tracing its history, we found that several years ago, in that particular city, one plant was started, which was named, after the system, the Thomson-Houston Company; in another part of the city, another, named the Edison Company, and in another part of the same town, the Brush Company; Mr. Jackson's analogy of the wall paper fits in very nicely in this case. It was soon found that these plants were not able to supply the requirements of the people and that their apparatus was out of date. At that time more modern machinery had come into existence, and so the proposition was entirely revamped physically and covered with a new coating of wall paper, in the form of a consolidation and a new bond issue; they went on and utilized that wall paper for a time, wore it out a little harder in spots in the center and not so much on the edges, and in the course of a few years, two or three more companies had sprung up in the central part of the city, and at the end of another five years it was necessary to give the whole situation another coat of wall paper,—effect another consolidation, discarding all of that equipment, and start all over again with an entirely new equipment. So that in tracing the money that had actually been spent, it is true that they had spent in the neighborhood of \$5,000,000, for which they can show at this time only \$1,200,000. At the same time the officers of that company, for want of information, are actually satisfied with their present rates and believe that they are really earning not only operating expenses but also the bond interest on the last plaster that had been put on to the property; they were perfectly content and felt that they were doing well; in fact, so much so, that a year ago there was just a little bit more than enough to pay the bond interest and the 2% which they were paying on their stock, and not knowing what to do with the money they suddenly remembered that the majority of these officers, who had been officers of one of the underlying companies, did not get any dividends in 1901, 1902, and 1903, so they appropriated \$58,000 of that money to the dividends which they thought were earned in those years but not paid. When it was suggested to them that there seemed to be no provision for a sinking fund and no provision for depreciation or any other items, they were, I believe, truly surprised that such was necessary. They had heard the terms but they had not seen the necessity of considering them in their property. As it happens, just at this time the examination is being made for the purpose of putting still another big plaster on the properties, for the reason that the community is very desirous of doing away with the unsightly poles and wishes to have

the company put all wires under ground. The equipment which they have at this time is in first class physical condition and they serve the people in the way they should be served; but it is unsightly in their eyes, and for that reason they feel that it ought to be discarded.

I am not making an attempt to discuss the paper or the subject, but am simply trying to illustrate, by this case, the necessity for serious consideration of obsolescence, depreciation, maintenance, etc., which have been so well brought out by Mr. Jackson. I know we are all grateful to the author for the paper presented, and I think a more careful study of the subject along the lines suggested by Mr. Jackson and also by Mr. Duffy will be very beneficial to all of us and to those whom we serve.

*Mr. W. L. Abbott, M. W. S. E.:* There is one particular point which Mr. Jackson touched on, which particularly interests me because I particularly disagree with him.

Mr. Jackson states that the useful life of power-house machinery would not exceed fifty years, but to be conservative he puts it at twenty-five or thirty years. I have been in the electric lighting business for about twenty-five years, and in that time I have seen the entire equipment of the lighting companies rendered obsolete and junked about four times. It will interest me to see how Mr. Jackson will provide for that rate of obsolescence in a manner that will harmonize with his statement that such equipment is good for twenty-five to thirty years.

*Mr. Jackson:* If Mr. Abbott will carefully read the part of the paragraph to which he refers, he will find that he has not quoted me correctly. What is said in that paragraph is:

\* \* \* \* "Let us consider a large high grade engine-generator set for alternating currents. Few of us would be willing to place at less than fifty years, the period during which such a machine should be physically capable of doing, under good care and management, the particular work for which it was designed; but no conservative engineer would allow, when estimating depreciation, that such a machine will have, in ordinary commercial electric service, a useful life of fifty years because advances of the art would inevitably affect its usefulness. In consideration of the great changes that have taken place in the past in apparatus for the generation and distribution of electric power, and the probable changes that will take place in the future, such a piece of apparatus cannot appropriately be allowed an estimated useful life of over twenty to thirty years." \* \* \* \*

If Mr. Abbott will consider the large, high grade engine-generator sets that have come within his experience he will see that the above statement is entirely within reason.

*Mr. Franklin H. Reed* (Asse. Mem. A. I. E. E., Editor of *Telephony*): Mr. Jackson has compressed a review of a very considerable number of points of interest into a brief paper. In doing so he is not only making a direct contribution to knowledge of the subject but, it is to be hoped, one which will have a still more valuable influence in extending the discussion and study of depreciation accounting, as an aid to the practice of sound finance.

Interest in this topic among operating men, at least in the telephone field, has greatly widened and increased during the past few years. A year ago last winter, it was very keen in certain sections of our north central states at the time sleet-storms were making their visitations. I recall one small company in Minnesota which preceded the addition of capital, like a layer of wallpaper, which forms Mr. Jackson's apt analogy, by raising its rates 25% after the wires tumbled down under a sleet load.

The possibility that depreciation funding will be omitted during the period of upbuilding is an interesting topic for discussion. In the telephone industry the process of upbuilding is practically continuous, and the company is confronted with the necessity of figuring on frequent expansions of plant. But usually within a moderate period the initial system has a very considerable earning efficiency.

During its period of early life, maintenance expense is very much lower per station than during subsequent years. So, although it may not agree with some present accounting theories, it is probable that many of the small plants would find it to their advantage to be a bit forehanded, as the saying goes, in providing their depreciation funds, and put the money away while current maintenance expenses are comparatively low, rather than to postpone the start to a later day.

There has been a tendency in the minds of some operating men to confuse the depreciation fund with maintenance expense. Maintenance expense is incurred to hold up the plant; the depreciation fund protects the investment. As long as inventive talent and organizing ability can command exceptional rewards, and real estate investments hold forth the possibility of unearned increment, the speculative element will enter into investments. Securities issued by public utilities will be obliged to offer a certain amount of speculative attraction in order to compete in the money market with other business. Yet it is an axiom, that any investment which appeals to the speculative element in human nature, presents a certain risk of losing which must be balanced against the hope of gain. The sentiment is coming to be widely held that public-service corporation funds should be characterized by safety,—investment with the speculative element reduced to a minimum. The public utility is pe-

cularly fitted to occupy the field of safe investment, owing to the slight liability to considerable reduction of income from any cause except bad management, and the steady and fairly regular expansion which accompanies the ever increasing natural demand for its service, which constitutes a modern necessity. If a public-service corporation accepts this view of its own investment standing, it irrevocably commits itself to the principle that an investor in its capital is entitled to withdraw his investment at his option. The property must be so managed that the man who pays in a dollar can take it out, and be sure that he will be able to do so one or ten years hence. Then he will have the same confidence in the safety and accessibility of his money thus placed as he does when it is put in the savings bank. This principle is the foundation of the ethical and business status of the depreciation fund.

An appropriate question for discussion, for some time to come, is likely to be the responsibility of the accountant in determining the actual rate of depreciation for the several classes into which a plant must be divided, as Mr. Jackson says, "in order that the average rate may be determined." While in all of the public utilities some parts of the plant will shift in character, so that obsolescence and inadequacy will have to be reckoned with in depreciation studies, yet we may well believe that certain other parts will be in use in a standard form and ratio, or approximately so, not only in present plants but in the ones which replace them.

For computing depreciation the engineer must have records, and a legitimate place for keeping such records is in the accounting departments of the operating companies. It will be interesting to see who will be the first to work out a satisfactory system of life accounting, which will give results of sufficient accuracy to be valuable in themselves, and at a cost sufficiently low to prove in the system.

*Mr. G. W. Cravens:* There are two or three points I would like to emphasize. It may have impressed some that this question is largely one of bookkeeping. Strictly speaking, all records are matters of bookkeeping, of course, but this matter of depreciation is more than that. A modern engineer has to be more than a designer and operator. It is also his business to see that the investments earn a fair return and are protected.

My own experience along this line has been largely with small plants, but my practice has been to divide this subject into three general heads:—maintenance, depreciation, and amortization, or, as it is sometimes called, a *sinking fund*. Depreciation proper is usually considered as meaning a reduction of value due to age, but it is really more than that. It applies to a process and, strictly speaking, it is a setting aside of a fund to cover contingencies, just as Mr. Jackson has brought

out. Maintenance, on the other hand, is an entirely different affair and applies to making repairs and replacements during the life of the operation of the equipment of whatsoever kind it might be. Amortization is the provision of a fund which will equal the amount of the original investment at the end of a given term. My ideas on this subject are given quite fully—from the physical standpoint, at least—in the number of the *Electrical Review* of April 23, 1910. That is an article on the depreciation of electrical equipment which will give more information than I can give in two or three minutes.

But I will say that the points brought out by Mr. Jackson are all good, and even though perhaps we cannot all agree with all of them, I believe such questions as this should be discussed more freely than they are. The best way to find out facts, usually, is to start an argument. In the article referred to, I tried to start an argument by taking a stand against the *equal annual percentages* usually set aside for depreciation. I think that a sort of sliding scale should be followed rather than an equal division. For instance, you say the life of a piece of apparatus is twenty years. We mean by that that its average length of life will *probably* be that. We all know that as soon as a piece of apparatus is put into service its value—*market value*, if you please—immediately takes a drop. In fact, we know that as soon as a piece of apparatus leaves the shop we cannot get as much money for it as we had to pay for it. Now, if the life of the property is normally twenty years, the chances are that its depreciation, if one tried to dispose of it, would be a good deal more than 5% the very next day after you purchased it. So, I believe that instead of setting aside equal annual sums for depreciation, the sum set aside at first should be, say, 10% or 15 %. That is, when I say *set aside* I mean *charged on the books*. We know that we cannot set aside 10% or 15% of the value of the plant the first year, because probably we will not have it, but it can be charged against it the same as a loan, exactly, and carried on the books and wiped out later in the days called the fat years, or when money is being earned in sufficient quantities to make up these deficits. Then, along the middle period of the life of this apparatus we can come down perhaps to 5% or whatever is considered fair; and along toward the end of the apparatus, when it begins to go to pieces, rapidly increase the rate of depreciation again, so that at the end of the time, say twenty years, the total amount set aside equals 100%.

That is, I think, a new point of view to most of you, but I have tried it, and find it works out very well, for this reason: it gives a book value more nearly equal to the *actual* physical value at any minute.

*Mr. Wray:* Mr. Cravens has raised a very interesting point.

I am wondering how he would apply the principle to a plant that is being added to each year—whether that would not complicate the situation, and complicate the method of applying the principle.

*Mr. Cravens:* In that case, I would handle each piece, or rather each class of apparatus, on a different basis. For instance, the rate of depreciation of a street car is very different from that of the transformers in a station. When new apparatus is added, I would account for that piece of apparatus as I would when the equipment was first installed. It gives more headings in bookkeeping, but, on the other hand, it gives a more accurate record. Depreciation of each piece of apparatus according to its own value—I mean, not physical value but its relative value in the general scheme—rather than classing all the apparatus together. Take, for instance, boilers. They depreciate much more rapidly than the electrical equipment, and should not be treated in the same way at all. Classify the equipment according to the service, and enter that apparatus, and depreciate each class according to its probable life, as well as its age at the time at which the inventory is being made. Some concerns have tried the practice of making an inventory at frequent intervals rather than predetermining a rate of depreciation. Small concerns can do that, but the big ones find it too bulky, although it is a very accurate method.

*Mr. J. R. Cravath, M. W. S. E.:* One thing that has impressed me in the numerous discussions we have had on this depreciation subject the last few years, has been the difficulty of drawing a hard and fast line between what is maintenance and what is depreciation. I have heard my friend, Mr. Duffy, discuss that at length, and yet I must confess that I have not in my own mind, and I think many others have not, a very clear idea of where we should draw that line. When we replace a piece of packing in an engine-piston, that is evidently a case of maintenance. When we replace the engine itself, that is evidently a case of depreciation. But it is not always so easy to draw those lines in the different parts of the physical equipment of a plant. When we replace one or two poles, we usually consider it maintenance, but if we are going to replace a number of them, do we call it maintenance? It is somewhat a matter of bookkeeping, and it makes a good deal of difference who is keeping the books.

*Mr. Weston:* I think that Mr. Ubelacker covered that point quite thoroughly when he said that in his judgment depreciation should come under one head, and that maintenance should cover it all. I believe that it is ordinarily divided in this way: that the maintenance of a property is covered by ordinary repairs, which probably would cover the replacement of a few poles, but where an entire line would be maintained or replaced it would be termed a renewal. My understanding of the word deprecia-

tion takes in all forms of physical wear, all forms of obsolescence, and in ordinary every-day accounting or maintenance of the property it is divided into the two parts of ordinary repairs and renewals, and the two combined cover the entire field of maintenance and also the field of depreciation.

*Mr. T. Milton, M. W. S. E.:* This subject has interested me more from the definition standpoint than from the standpoint of real depreciation. It seems to be unanimous that it is necessary to set aside money or, on the books anyhow, set aside something to take care of the wear and tear. Some people call it depreciation and some call it maintenance. For myself, I like the definition that Mr. Jackson has given and the way he splits it up, because I have had to maintain that, and I have to do so nearly every day. The storage battery people claim that there is no depreciation on batteries, and I think that my argument has always been along the line of the definition which Mr. Jackson has given. He splits depreciation under two heads—decrepitude and obsolescence—and defines decrepitude as the gradual wearing out of apparatus which cannot be overcome by current repairs. Now, a battery is a peculiar piece of property. When a plate or a piece wears out, by putting in another one of those pieces the battery can be brought up to capacity. It does not pay to leave a plate or part of the battery in bad repair, because it throws the whole apparatus out of good order. The consequence is that by making continual renewals and keeping up the battery, we always class it under one head as maintenance. I believe there are pieces of apparatus which may have depreciation. For instance, I think the boosters and switchboards in the battery plant undoubtedly must have some depreciation, but in the battery proper, according to Mr. Jackson's definitions, I do not believe there is any depreciation.

It all comes back to the point, what do you mean by depreciation? When we begin to talk about depreciation and maintenance, everybody seems to have different definitions. Personally, I prefer Mr. Jackson's definition, because, under the obsolescence head, so far in the history of the lead storage battery at least, there has not been much change in the last twenty odd years; in fact, practically none; and certainly a battery plant can be maintained by current repairs. It does not deteriorate simply from old age.

*Mr. E. N. Lake, M. W. S. E.:* The hour is so late I will call attention to only one point. It seems that the discussion of the evening has centered entirely on depreciation. There is one question in connection with this matter of reserve that I would like to ask. One speaker of the evening refers to an adequate estimate of a suitable yearly contribution on account of required construction based upon the requirements that are likely to be imposed in the future by municipal ordinances. I would like to

ask if he has any special basis for the application of the theory of probabilities by which he can arrive at what any given City Council is going to do?

*Mr. Weston:* Before Mr. Jackson begins his closure I would like to refer to his paper where he advocates the establishment of a reserve fund, or rather he advocates that in the determination of the life of an apparatus the depreciation and obsolescence feature be considered in calculating that life. In the remarks made by Mr. Ubelacker, he stated that he did not see the necessity or the justice in establishing a reservation fund to take care of the supersedence of apparatus, but that he thought where a piece of apparatus should be superseded on account of its inadequacy or for other reasons, the advantage due to the improved conditions resulting from the installation of the new apparatus should take care of the added investment. How is he going to provide for payment for the new apparatus at the time that it is installed, without a reserve fund or without adding it directly to capital account?

*Mr. Ubelacker:* I think that perhaps Mr. Weston did not catch the drift of the point I was making. I said if we are establishing a rate for service given, using as the basis for establishing that rate the cost of giving that service, why should we charge on the man, the customer, who is getting the service of plant A, which is going to be later superseded by plant B, the cost of superseding plant A, which gives an inferior service to plant B? Why is not the man to carry the loss which we have to take up when we put in the improved service, the man who gets the improved service? In other words, why is not that where the cost of that service ought to go in the rate? I am not saying that this is what we ought to do. I am asking why not? It is a question we have to come up against many times when a rate is being established. The other reason that I gave for the possibility of taking that view is the fact that the basis on which we supersede apparatus is that the superseding apparatus will pay its way by either its reduced cost of operation or its larger earning power, which answers Mr. Weston's question as to where we would find the money to take up the last of our charges, the difference between the new cost of the superseded apparatus and its selling value when superseded.

*Mr. Weston:* No, it is not made clear to me where the man that is going to buy that apparatus is to get the money to pay on the bill of lading or on a sixty or ninety day credit, and what disposition is the auditor and controller of the company going to make of that expenditure?

*Mr. Almert:* Mr. President, I cannot quite get the drift of Mr. Ubelacker's remarks either. I can remember when we used to ride in old horse cars in Milwaukee, without any heat in them and with only straw to keep our feet warm, a very short

distance and very slow service by horse power, and the price was then five cents. Today they have the latest up-to-date cars with all conveniences, a first-class roadbed, a high speed running schedule, and very much better service, and the price is still five cents, or less. On Mr. Ubelacker's theory, I do not know in what section of the country we will operate, where the franchise will permit us to raise the rates when those conditions obtain or where we would have patrons that would stand for it and understand why the rates were increased. I cannot see where the money is to come from.

*Mr. Wray:* I would like to add another point, as I believe, against the position Mr. Ubelacker has taken, and that is in the question of improvements which are made to better the service without necessarily improving the earnings or reducing the cost of the service. It seems to me that the policy advocated would tend to delay improvements of the service or delay the adoption of methods or apparatus which would improve the service.

*Mr. Ubelacker:* I think that any over-estimate of depreciation is going to have exactly the effect mentioned. It is going to delay the adoption of improvements. That is one reason why I am very doubtful as to the good policy, either from the public standpoint or from a financial standpoint, of over-estimating depreciation, or of over-emphasizing it. The point just brought out—the fact that one is paying now for good, modern service transportation at the rate of four cents, where previously he paid five cents for a very much poorer rate of transportation—brings out the other point I was trying to make. There is no justice in our paying less now for a good service than we previously paid for a poor service, and the reason that we are doing it is just because you do not answer the questions I have asked here tonight, in the handling of rates. That is, what is the justice of assessing against the man in the early days the cost of superseding the apparatus which is giving the poor service, and then giving the man in the later days that gets the good service the benefit of the fact that the man in the earlier days has paid for that supersession. The man that gets the service ought to pay the cost.

*Mr. F. Schumacher, M. W. S. E.:* I would like to answer Mr. Ubelacker's question this way. In 1907 there were two companies—I will name them, for instance, the United States Steel Corporation and the Westinghouse Electric Co. The United States Steel Corporation made liberal provisions for a surplus fund and a depreciation fund. In the panic of 1907 it built up the Gary plant out of its depreciation fund and the Westinghouse Electric Co. went into the receiver's hands. So the Steel Corporation, I think, followed up Mr. Jackson's theory of finance and the Westinghouse Electric Co. did not. This simply shows where that

leads to, if all profits are divided among shareholders, and no provision is made for an adequate reserve fund.

*Mr. A. W. Stager:* The present business I am engaged in with the Sanitary District is the purchasing end. Of course, I have been largely interested in the rates they are now making to the public. The point that has especially impressed me is the apparent disagreement of the various members present with Mr. Jackson's views. They all said it was a good paper but still they all had their own opinions about the subject. The question of depreciation seems to have many different angles,—many different quantities, I might express it. One man thought that maintenance was the greatest part of the charge. Another man thought depreciation should bear the larger portion of the charge. With our plant we have just lately installed a cost system that has enabled us to get at the exact facts in connection with the operation as well as the original investment of the plant, but those figures have not as yet been reduced to such a state that they can be put before the public in an intelligent manner.

#### CLOSURE.

*Mr. Jackson:* I want to emphasize the fact that one of the chief thoughts I have in presenting this paper is to get people away from the idea that depreciation may be treated as a secondary consideration and may be considered as a mere juggling of figures by the bookkeeper. What I wish to see is this matter of depreciation handled intelligently and logically, so that the books of the company will show the actual facts of the cost of service. I can feel entirely justified in going before any fair-minded person with a carefully considered scale of rates, if I can say these rates are fair because they are based upon the cost to the company to provide the service, and in these rates I have allowed for annual appropriations to the depreciation and reserve funds; the estimates for such annual appropriations are based upon as complete information as is available. And I can truly state that the actual cost to the company of the service is as estimated, notwithstanding that the company may spend during any particular year possibly only one-tenth or maybe one-twentieth of the average amount of money that must be appropriated annually for depreciation and reserve funds. I know that such annual appropriations are a part of the cost of the service, owing to the fact that the company must eventually have money to replace the plant that will go out of service from obsolescence or from decrepitude, or that they will require the money for some unforeseen contingency which we can only estimate. To deny this would be on a par with saying that the earnings from a successful mercantile business need not be sufficient to cover the cost of replacing the office furniture and fixtures, horses and wagons, and other equipment when these

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are worn out and no longer serviceable, and that the cost of such renewals might appropriately be taken out of the capital account.

I would like to emphasize what Mr. Almert said, that some companies today are allowing their rates to be forced down below a profitable level because they do not know the real cost to them of the service they are providing, or because they do not have the courage of their convictions, and the reason that they do not have the courage of their convictions is frequently that they have not intelligently and logically worked out what depreciation in plant actually means to them and what amounts of money they must in the near future pay out to replace plant that is worn out or that must be replaced for one reason or another. Today there are many plant managers who are worrying to know where they can obtain the money to replace parts of their plant that they know must be replaced this year or at some future period, because they cannot or should not float more capital to take care of those costs, and they have not accumulated funds for that purpose.

Another feature is this: suppose a company does not take care of the depreciation and reserve funds so that they can have appropriate apparatus for providing their service when their old apparatus becomes antiquated or worn out. They will be seriously handicapped if they are called upon to stand against competition from a new and ably engineered and operated competing plant, equipped with the best and most economical equipment, whether it is under private or municipal ownership.

The question of depreciation and appropriate reserve funds are not matters of mere bookkeeping. They are financial matters, it is true, but they are highly important financial matters, and their proper treatment is one of the factors that goes right to the heart of the successful operation of public-service corporations of today.

If, as Mr. Weston advocates, the factor of obsolescence is not included in the consideration of depreciation, one of the very important elements of depreciation is omitted, and those responsible for a company's welfare do not take full advantage of their right to keep the property of the stockholders in its best possible condition.

In reply to one of Mr. Ubelacker's questions, the patron of today is not asked to pay for the equipment of the patron of tomorrow under an appropriate arrangement of appropriations to depreciation and reserve funds, for he is simply asked to pay for the use of the property he is interested in. Any replacement that puts more costly plant in place of less costly should add to the capital value of the plant by the amount of its additional cost, and such additional cost does not affect conditions until the replacement is actually made.

In closing I wish to say that any consideration of depreciation and reserve funds, such as is found in this paper, must be considered as an annunciation of general principles rather than of specific applications. As is pointed out in the paper, though possibly not as fully as might be desired, every company must expect to have its fat and its lean years. But it is nevertheless highly important for the best interests of a company to know, within a reasonable degree of accuracy, what proper appropriations to depreciation and reserve funds are, so that they will know how much they are short of such appropriations during lean years and how much they must expect to appropriate when the fat years are at hand. This entails the fullest knowledge of their depreciation and reserve fund requirements and an adequate system of bookkeeping to show the facts.

# ECONOMIC CONSIDERATIONS GOVERNING THE SELECTION OF ELECTRIC RAILROAD APPARATUS.

BY F. DARLINGTON OF PITTSBURG.

*Presented June 7, 1910.*

There is often great variance of opinion or serious doubt among engineers and railroad men as to the relative merits of the three electric railroad systems that are more or less in common use. It is the purpose of this paper to discuss the matter briefly from the standpoint of economy of construction and operation. It is not intended to discuss the economical value of electric motive power compared with steam power, except to point out at the outset that the high cost of electric equipment is the chief thing that prevents the rapid extension of railroad operation by electric power.

There is no general rule by which the cost of electrical equipment for railroads can be determined because this cost is affected by such a great variety of conditions; for some parts of the equipment it depends on the weight and frequency of trains and the power used per train and for other parts it depends on the length of track to be electrified and on local conditions.

There are three distinct parts in the equipment required for every electric railroad system:

- (1) The electric power generating plant.
- (2) The electric power transmission and distribution system, including substations or transformer stations.
- (3) The motive power apparatus, viz., the electric locomotives and electric cars.

Of these three parts the cost of the power plant and of the motive power apparatus, which is the locomotives or motor cars, varies with the total amount of power required for train propulsion at times of heavy traffic movements. On the other hand, the cost of the power transmission and distribution system varies with the length of the track equipped, with the maximum total power required and with the maximum power that may be concentrated at any place on the line.

## VARIATIONS IN TRANSPORTATION REQUIREMENTS.

*Train Weights.*—Railroad service varies according to the requirements of traffic and the motive power of railroads must operate trains of different weights from light single car trains of 25 to 60 tons each, as on interurban electric roads, to heavy freight trains sometimes of 1000 or 2000 or more tons each. Increase of train weight tends to reduce operating expenses, and consequently railroad practice is steadily making trains heavier and heavier.

*Train Speeds.*—Trains must be operated at varying speeds since some kinds of traffic demand higher speeds than other kinds, and on every railroad there are some places where it is safe and economical to run faster than at other places. To meet the needs for quick time and to utilize railroads to the best advantage, it is necessary that speeds be adjusted to passing conditions of tracks, or for grade, or for regard to cautionary signals, or for standing on sidings, or a thousand different and ever varying matters. Since the business of railroads is to move traffic in the greatest quantity and in the shortest time practicable at reasonable cost, train speeds must be kept always at the maximum that safety and economy will permit, and since conditions of safety and economy vary with every run and with nearly every mile of every run, the



Fig. 1.—B. & O. R. R. Co., D. C. Electric Locomotive for Tunnel Service in Baltimore.

required speed varies from the lowest speed or standing still to the highest speed and therefore railroad motive power should be economical at all speeds.

#### DENSITY OF TRAFFIC.

The density of railroad traffic may be anything, from one train each way per day on some roads, to as many trains as can be crowded over the tracks on some other roads. On some roads the traffic may be best served with single cars, as on interurban trolley roads or where gasoline motor cars are used, while on other roads it may be best served with maximum weight trains, either passenger or freight, as is common on many main lines.

## POWER PER TRAIN.

This depends, of course, on the weight and speed of trains, on the grades to be climbed, on the stops and starts required, etc.

Since the total power and the tractive effort required vary according as the train is standing still, or is being accelerated, or is running at maximum speed, or is climbing a grade, or is coasting down grade, the power and tractive effort are constantly varying from zero to maximum. A locomotive of 1000 H. P. will handle a 1000 ton train under certain conditions of speed grade, etc., but under other conditions 1000 H. P. or more may be required for a 250 ton train, or a 50 ton electric car may in certain



Fig. 2.—N. Y. C. & H. R. R. R., D. C. Electric Locomotive and Train in New York City Terminal Service.

kinds of service require 400 to 500 H. P. per car to make its schedule.

## AMOUNT OF LOCALIZED POWER REQUIRED ON RAILROADS.

Modern steam railroad trains on main lines use locomotives capable of delivering 700 to 1400 H. P. or more each, and trains are often passing or following or double headed so that even on single track roads 2000 to 4000 or more horsepower may be required by trains within comparatively short distances of each other.

Wide variations in all of the above factors, that is in train weights, train speeds, density of traffic, power per train, and power concentrated at local points on a railroad, may occur at different times and places on a single railroad or section of track. All of these conditions must be met by railroad motive power.

## CHOICE OF SYSTEMS.

Which of the three well-known electric systems, each of which has its ardent and often partisan advocates, is best adapted to meet all of the variable conditions?

The systems are:

- (1) The Direct Current System.
- (2) The Single Phase System.
- (3) The Three Phase System.

EACH SYSTEM DIFFERS RADICALLY FROM THE OTHERS.

The electric motors used in each system are fundamentally different from the motors used in the other two systems, and require a different kind of electric current for their operation, and this necessitates for each system different apparatus for the distribution of the electric power.

I propose to discuss the relative merits of the three systems briefly from the standpoints of reliability and of economy of construction and operation.

POWER PLANTS FOR THE THREE ELECTRICAL SYSTEMS COMPARED.

The electric power generating stations are usually steam turbine or hydro-electric plants. Gas engines have not come into extensive use for furnishing power to electric railroads. The cost and efficiency of the power plants for the three systems do not differ greatly, for although single phase generators are more costly than the three phase generators used for the other two systems, the total engine and boiler power usually has to be somewhat greater for direct current and three phase than for single phase operation. This is because the losses are greater in direct current trolleys or third rails, and in direct current sub-stations than in single phase trolleys and transformer stations, and because three phase motors under ordinary railroad conditions make greater fluctuations in the load on the power plant than single phase and direct current motors do. In spite of the greater capacity in engines and boilers for D. C. operation of railroads than for single phase, it may often occur that the K. V. A. or apparent electrical output will be greater for single phase than for direct current service due to the difference in the power factor of the current supplied.

For three phase main line railroad electrical operation the power plant will generally be somewhat larger and more costly than for either direct current or single phase. This is especially the case where variable heavy grades are encountered or where heavy trains are frequently accelerated, and is caused by the characteristics of three phase motors which tend to make high peak loads on the power plant when worked at the widely varying tractive efforts and speeds usual in railroad work. This will be discussed later.

Under most conditions, the total of the variations described does not cause a large difference in the cost of the power plants required for the three electric railroad systems.

Ordinarily the cost of steam turbine plants for railroad electrical operation is somewhere in the neighborhood of 25% to

40% of the total cost of electrical equipment. It more closely approaches the larger proportion of the whole cost when the traffic is dense, requiring a large supply of power per mile of track, or where high tension single phase trolleys are used, which by their relatively low cost reduce the total cost of electrical equipment, thereby making the cost of the power plant a larger proportional part of the whole electrification cost.

POWER TRANSMISSION AND DISTRIBUTION LINES AND EQUIPMENT, INCLUDING SUB-STATIONS OR TRANSFORMER STATIONS, COMPARED FOR THE THREE ELECTRIC RAILROAD SYSTEMS.

The power transmission and distribution system forms the link between the power plant and the electric locomotives or cars. It consists of trolley lines or third rails, of feeder cables, of track bonding, of sub-stations, and of high tension transmission lines. The aggregate cost of these items is the largest or at least a very large part of the total cost of electrification for heavy railroad operation. Where direct currents are used the power transmission and distribution apparatus generally costs more than either the power plant or the electric locomotives and motor cars, and is liable to be between 40% and 60% of the total electrification cost, and is especially high where heavy trains are to be operated requiring large units of power distributed over long sections of track. Under these conditions, even where advantage is taken of the most modern improvements, using 1200 volts direct current on trolleys or third rails, the cost of direct current distribution apparatus is still the largest cost item for electrical equipment.

Where single phase apparatus is used the electric power transmission and distribution system is greatly simplified and cheapened. A single high tension trolley wire is substituted for the trolley wire or third rail and feeder cables of the direct current system, and static transformer stations are substituted for direct current sub-stations in which there are both static transformers and rotary converters or motor generators. The single phase trolley system is equally suitable for light infrequent service and for heavy dense service or for large units of power infrequently operated. The sub-stations are widely separated, and their cost, as well as the cost of the distribution conductors, is much less for single phase than for direct current, so that the combined cost of the sub-stations, and transmission and distribution conductors, may be fairly stated under average railroad conditions to be about one-quarter to two-thirds as costly for single phase as for direct currents.

Where three phase apparatus is used, high tension alternating current trolleys are employed and three conductors are necessary to carry the current for three phase motors, so that two separately insulated trolley wires are necessary in conjunction with the track rails.



Fig. 3.—St. Clair Tunnel, G. T. Ry., Single Phase, A. C. Electric Locomotive.

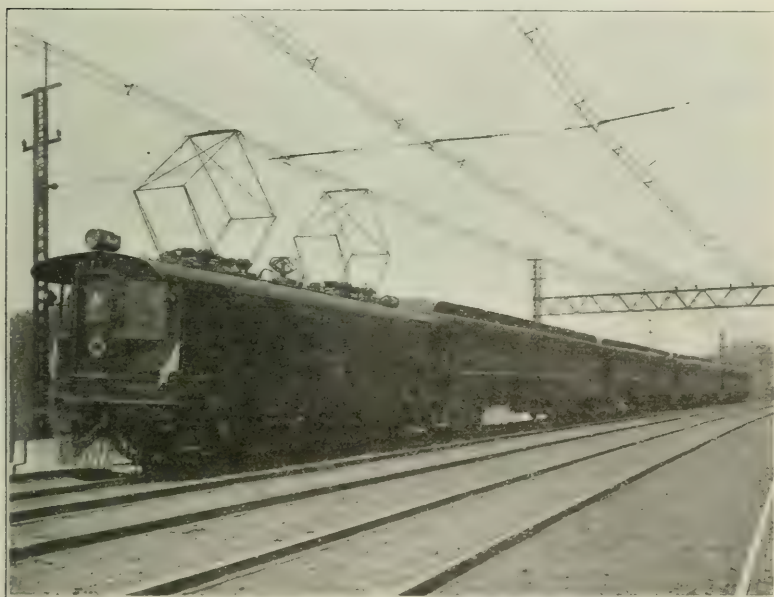


Fig. 4.—N. Y., N. H. & H. R. R., A. C. and D. C. Electric Locomotive and Passenger Train, New York City Terminal Service.

October, 1910

Three phase motors, as will be hereafter explained, can be built for working on higher potentials than can either direct current motors or single phase motors as ordinarily used. For this reason the potential employed on three phase trolley lines is usually applied directly to the motors without intermediate reducing transformers carried on the locomotives or cars. The desirability of working the motors without transformers, combined with the difficulty of separately insulating two trolley conductors for very high potentials, has generally prevented the use of as high potentials on three phase trolleys as are common on single phase trolleys. The latter are often built for 11,000 volts potential on the trolley, while according to present practice 3300 volts is usual and 6600 volts is high for three phase trolleys, though in the latter case reducing transformers are generally used on the trains.

Three phase motors for their successful operation under the varying loads encountered in railroad work require more uniform potential supplied to them than is required by either single phase motors or direct current motors, and in order to maintain better potential regulation on the trolley at the relatively low voltages at which three phase trolleys are generally operated as compared with single phase trolleys, it is necessary to locate transformer stations closer together on three phase lines than on single phase lines. For heavy trains the number of transformer stations will generally be more than double as many, and under certain conditions, three or four times as many for three phase as for single phase installations.

There is another thing about three phase transformer stations for railroads that is becoming more important than it was a few years ago when it was not practical to use as high a potential on transmission lines as can be advantageously used today. Three phase transformer stations require either one three phase transformer or three single phase transformers. It is much more costly to build one very high voltage three phase transformer or three single phase transformers than one single phase transformer of the same aggregate output. In other words, the cost of transformers per kilowatt of capacity is very much greater for three small units than for one large unit, especially when they are for very high primary potentials such as 100,000 or 110,000 volts. It is now well established that 110,000 volts or thereabouts will be widely used in large long distance power transmission schemes, the increase in potential over the practice of a few years ago having been brought about largely by improvements in line insulators, especially of the suspended type.

I cannot state just what the relative cost of three phase and single phase power transmission and distribution systems will average for the ordinary requirements of railroads, but it is clear that with two trolley wires for the three phase system instead of one wire as for single phase, and with transformer stations two or

three times as frequent for the three phase as for the single phase system, the cost for the three phase system will be considerably increased, and will probably average somewhere from 30% to 80% more for three phase than for single phase.

RELATIVE WEIGHT AND OPERATING CHARACTERISTICS OF DIRECT CURRENT AND OF SINGLE PHASE AND OF THREE PHASE ELECTRIC RAILROAD MOTORS.

The three distinct types of motors used in railroad work determine the three standard systems, that is, the direct current system, the single phase system and the three phase system, and the motors all differ in cost and weight and method of operation.

*Direct Current Motors.*—The different types of motors may be conveniently compared by taking the direct current motor as the basis of comparison, since it is the oldest and best known in railroad work. It should, however, be noted in this connection that only

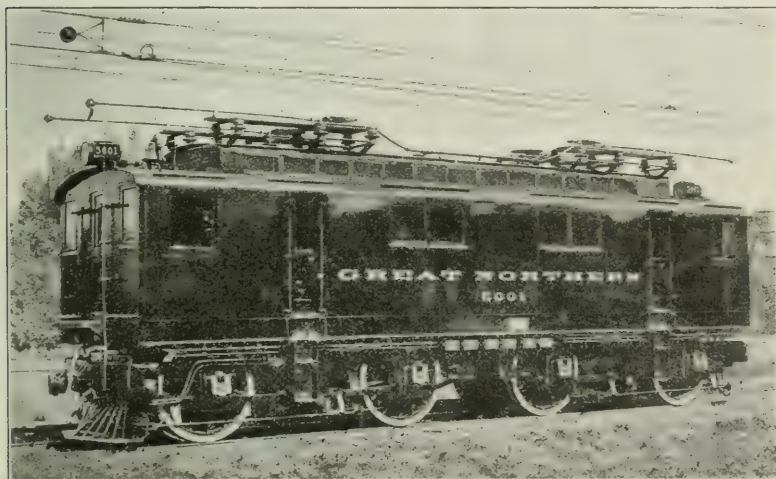


Fig. 5.—Great Northern R. R., Three Phase Electric Locomotive, Used in Cascade Mountains, Tunnel Service.

within the last few years have direct current railroad motors been commonly built with so-called commutating poles and they are now known as inter-pole motors, and the new construction has greatly improved them. Formerly the capacity of direct current motors for heavy sudden overloads was limited chiefly by commutation, and the maximum voltage for which they were practically built was somewhere between 600 and 700 volts. The use of inter-poles has considerably increased this limit, especially for large motors, and has largely done away with sparking on the commutator and flashing over, so that now overheating is the principal

thing that limits the capacity of direct current motors of the latest design.

*Single Phase Motors.*—Single phase motors for railroad work are very similar in construction and in operating characteristics to direct current railroad motors. They are series wound, variable speed motors, and have compensating windings. Their compensating winding is differently arranged from the inter-pole windings of direct current motors, but performs a similar function which is to improve commutation, and at the same time it improves the power factor by reducing the self-induction of the motors.

Single phase motors are generally designed to work with variable voltages up to about 350 volts maximum applied to the motor, and experience has pretty well demonstrated that when everything is considered, 15 cycles or thereabouts is the best current frequency to employ.

High potentials are used on single phase trolleys and whatever the potential may be, whether 11,000 volts or more or less, the potential is reduced for the motor by transformers carried on the locomotives or motor cars. There is one type of single phase motor called a "repulsion" motor that is used in Europe to a limited extent. It is practically a motor and transformer combined and is heavier than ordinary single phase motors, but 11,000 volts, which is a common and economical single phase trolley voltage, is too high for economy and safety on repulsion motors without separate transformers.

An important difference in operation results from the difference in the motor control apparatus used for direct current and for single phase motors. Direct current railway motors are governed to vary the speed and tractive effort by connecting them in series and in parallel, by varying the field strength, and by inserting resistance in the circuits to regulate the flow of the direct current. Single phase motors are governed in speed, etc., by applying varying potentials to them from different potential taps on the transformer from which they get their current supply. Thus the transformers serve the double purpose of reducing the potential for the motors and varying it to govern the speed.

Single phase railroad motors are heavier and more costly than direct current railroad motors of the same capacity. Designers state that the difference is somewhere between 10% and 25% in weight and 25% to 50% in cost in favor of direct current motors as compared with single phase motors. The transformers required for single phase electric locomotives will generally constitute about 5% to 10% of the total locomotive weight, and the motors themselves will generally constitute about one-quarter to one-third of the locomotive weight. Additional weight seldom has to be put into the locomotive frame and running gear to carry the extra weight of the transformers and single phase motors when compared with direct current motors, because when the locomotive frame

is designed with sufficient strength to withstand the shocks encountered in operation it is strong enough to carry all the load put upon it with single phase apparatus. There are so many conditions entering into the design of electric locomotives that it is very difficult to determine an average difference in weight between direct current and single phase designs with any reasonable approximation. For one thing, the need for series parallel control with direct cur-



Fig. 6.—N. Y., N. H. & H. R. R., Single Phase, A. C. and D. C. Motors Mounted on the Truck.

rent makes it necessary to always use either two or four motors to get an even number for connecting in series, when one or three motors might otherwise be lighter and more convenient, and of course there is no need for series parallel control with single phase motors. Then again the entire weight of any electric locomotive is sometimes necessary to get sufficient adhesion to the track to prevent slipping the driving wheels. This occurs in many designs of single phase freight locomotives so that if the weight were not in the mechanism, cast iron or other weights would have to be added to get adhesion.

In locomotive design we might perhaps reasonably say that if single phase motors are 25% heavier than direct current or three phase motors, the additional weight would be 8% of the weight of the locomotive and that this weight and 7% additional for transformers would make single phase locomotives 15% (more or less) heavier than direct current locomotives.

As already explained this extra weight will often not be objectionable from an operating point of view for freight locomotives, as it may be necessary to secure adhesion, but extra weight of machinery of course always makes extra construction cost, and it will almost always be objectionable in operation, as well as in first cost, with high speed passenger locomotives. I want to caution you that 15% is not a uniform factor for difference in weight

between direct current and single phase locomotives for, under some circumstances, single phase locomotives may actually be lighter than equivalent direct current locomotives, or, on the other hand, under certain circumstances they may be more than 15% heavier than direct current locomotives.

PROPORTION OF THE COST OF ELECTRIC LOCOMOTIVES AND ELECTRIC  
EQUIPMENT OF CARS TO THE WHOLE COST OF RAILROAD  
ELECTRIFICATION.

It is difficult to give an approximate ratio between the cost of electric locomotives and electric apparatus on motor cars and the whole cost of equipping railroads for electrical operation.

For complete divisions of 100 miles or more on a single track main line railroad, where the trains are heavy and frequent, the cost of electric locomotives may be 25% to 40% of the total cost of electrification, but where the trains are lighter and less frequent this will be reduced to say 15% to 25% of the total cost. On this basis, if single phase locomotives cost more than direct current in proportion to twice the difference of their weights, or say they cost about 30% more, this difference in cost between single phase and direct current locomotives will amount to about 4.5% to 12% of the total cost of railroad electrification, but under ordinary conditions this is many times offset by the higher cost of power transmission and distribution by direct currents than by single phase currents.

On interurban electric roads, operating cars at one hour to one-half hour headway, the cost of the motors and electric equipment on the cars for direct current apparatus may be about 5% to 8% of the total electrification cost, and it is about one-quarter to three-quarters greater for single phase apparatus, including transformers, etc. On interurban lines except where they are very short the difference in cost between direct current and single phase motors is generally more than offset by the saving in cost of single phase power transmission and distribution apparatus, and on long interurban lines the difference is a good many times offset even where 1200 volts is used for direct current distribution.

THREE PHASE MOTORS AND THE EFFECT ON RAILROAD OPERATION OF  
THEIR CONSTANT SPEED CHARACTERISTICS.

Three phase motors, unlike direct current and single phase motors, tend to maintain constant speed at all loads. They are light and durable and cheap to build. Their advocates claim that on their continuous rating they are lighter and cheaper than direct current railroad motors of the same capacity. I am not certain on this point as regards weight, especially since direct current motors have been so greatly improved by commutating poles and improved design. Large size three phase motors have somewhat

greater continuous horse power capacity than direct current railroad motors of the same outside dimensions, but they are usually heavier than direct current motors of the same dimensions. In any event, it is entirely immaterial for railroad work how the two types of motors compare at their continuous rating, because there is very little railroad work in which the motive power is operated at a constant rating or at uniform speed and tractive effort. The important consideration is, which motor is the best, the lightest, and the cheapest for the varying speeds and tractive efforts required in propelling railroad trains. Simple three phase motors are very inefficient at all speeds but normal constant speed, except where a certain device is employed by which it is possible to operate three phase motors at good efficiency at exactly half normal speed, or by another device at exactly double normal speed. Each of these devices, which are known as cascade connections and pole changing devices, require special appliances, and the use of both on one locomotive or motor car in order to get good efficiency at both half speed and double speed as well as at normal speed would be very troublesome, except possibly for low voltage motors for which transformers would have to be carried on the locomotives. Neither of the devices give good efficiency at intermediate speeds or at starting, and as a consequence three phase motors are not so well adapted as other railroad motors for work requiring frequent starting or frequent variations in tractive effort and speed. Other speed combinations than the above are possible but add still further to the complication.

One of the results of constant speed operation, as I mentioned before, is to cause very heavy demands on the power plant when heavy traction is needed. This may be best made clear by referring to a specific condition. Suppose a 2000 ton train is running at thirty (30) miles an hour on a level track, it will require 14,000 lbs. tractive effort to propel it. The horse power exerted will be 1120. If the same train encounters a 1% up-grade the tractive effort required will be 54000 lbs. and at the same speed, namely 30 miles an hour, the horse power exerted will be 4330 which would make a heavy peak demand on the power plant, and this could be reduced only by using a half speed device. There is another important thing to be considered where constant speed is maintained, whether it be 15 miles per hour or 30 miles per hour or any other constant speed, and that is that no advantage can be derived from velocity head, or what engineers call a "running start." If the speed is constant, the extra work on grades must be supplied just as it occurs without assistance due to momentum, and corresponding power must be supplied by the power house, resulting as in the previous case in heavy peak loads. But even aside from the motors and power plant there are very few instances where the best economy and safety can be had by running trains at a constant speed. There are places where it is desirable to run fast and other

places and occasions where it is best to slow down and in practical railroading these conditions are encountered continually.

The variable speed characteristics of direct current and single phase motors readily permit a reduction in train speed when the tractive effort is increased, in fact unless controlled by the motor-man, these motors will automatically reduce in speed with increased tractive effort, thus helping to keep down the total power demanded at the time that tractive effort is greatest. On the opposite side of the case, where the track is level and straight and high speed is desirable, a three phase motor cannot exceed a certain fixed speed, whereas a variable speed motor, especially a single phase variable speed motor that can be supplied with extra high potential from *over voltage taps* from the transformer, can take advantage of this opportunity to make extra good time; also trains equipped with variable speed motors can take advantage of velocity head or a running start in climbing short grades.

#### RELIABILITY OF ELECTRIC RAILWAY APPARATUS.

Reliability of motive power is of prime importance in railroad-ing and any acceptable railroad motor must be reliable. Fortunately experience has established a pretty good degree of reliability for electric motive power.

*Reliability of Single Phase Motors.*—Much speculation and some doubt has been current regarding the reliability of single phase railroad motors. This should be set at rest by the results accomplished with them.

The largest single phase installation is on the New York City Terminal of the New York, New Haven & Hartford Railroad, where there are 40 or 50 1000 H. P. single phase locomotives in interchangeable operation between 11000 volts, 25 cycles, single phase current and 650 volts direct current.

This installation is demonstrating a high degree of reliability, not only for the motors, but for the entire electrical plant and equipment. On some days every electric locomotive has been in service, none being in the repair shops. Such a thing would not occur with forty or more steam locomotives. The number of electric locomotive miles made per motive power delay on the New Haven road has averaged, for several months at a time, one failure or delay in 15000 to 17000 locomotive miles. This is two or three times as many miles as is averaged per motive power delay with steam locomotives in the same kind of service.

The heavy single phase freight locomotives in service on the Grand Trunk Railway in the Detroit River Tunnel between Port Huron and Sarnia likewise give very reliable service.

Including interurban electric roads there are over twenty (20) single phase electric systems in operation in America, and over twenty-five (25) in Europe, and while minor difficulties have been encountered in some places an excellent operating reliability has been demonstrated for single phase apparatus.

*Reliability of Three Phase Motors.*—There is not so much practical railroad experience upon which to base judgment regarding the reliability of three phase motors as there is for direct current and single phase motors, but such railroad experience as there is, together with the extensive use of three phase motors for industrial work, points to an excellent degree of reliability that is unexcelled in any type of motor.

*Reliability of Direct Current Motors.*—The wide use of series wound direct current motors by railroads has thoroughly established their reliability.

#### COST OF MAINTENANCE OF ELECTRIC MOTORS AND LOCOMOTIVES.

Time will not permit much discussion of locomotive maintenance costs, but experience has demonstrated that it will average less for well constructed electric locomotives of all types than for steam locomotives.

In America the maintenance cost of the heavy direct current and single phase electric locomotives in use on various railroad systems is low in all cases. The roads using heavy electric locomotives are:

(1) The Baltimore & Ohio R. R.—Direct current locomotives used in tunnel in Baltimore.

(2) The New York Central R. R.—Direct current locomotives used on New York City Terminal.

(3) The New Haven R. R. interchangeable single phase and direct current locomotives used between New York City and Stamford, as already mentioned.

(4) The Grand Trunk Railroad.—Single phase locomotives, previously mentioned, used in the Detroit River Tunnel.

An interesting tabulation of the comparative cost of repairs for steam and electric locomotives has recently been published by Mr. L. R. Pomeroy in a paper presented before the Engineering Society of Columbia University. He segregates the items of repair cost for both steam and electric locomotives and gives the total cost of repairs of electric locomotives at about 40% of the cost of repairs of steam locomotives. He gives a little over one-third of the total cost of electric locomotive repairs as belonging to the motors, the remainder being for repairs of running gear, for painting, etc.

It is reasonable to suppose that single phase motors being more costly and somewhat heavier than direct current motors will cost more for repairs, but even if the cost of repairs on single phase motors should be 25% more than on direct current motors, this increase will add less than 10% to the total cost of locomotive repairs, provided Mr. Pomeroy is correct in his estimate, which gives the repairs of electrical machinery as three-eighths of the total cost of electric locomotive repairs. Likewise for three phase locomotive, since the repairs on the motors are only a small part of the cost of repairs on the whole locomotive, the possible saving by the

use of three phase instead of direct current or single phase motors can never be a relatively large item. As regards motor cars the cost of repairs of the electric equipment has long been known to be very low.

#### EFFICIENCY OF DISTRIBUTION SYSTEMS COMPARED.

Brief mention has already been made of the difference in efficiency between the direct current and alternating current electric power distribution systems, but without giving relative figures.

All moderate and large size direct current railway systems employ rotary converter or motor generator sub-stations located at frequent intervals along their tracks to change the alternating current from the high tension lines to direct current for the trolley or third rail. The apparatus in direct current sub-stations includes moving machines that are necessarily operated much of the time under light loads; also the drop in the direct current trolleys or third rail at time of heavy loads is large, and the average result is that on direct current systems much electric power is lost between the power house and the trolley wheels or other collecting devices on the trains. On many large direct current railroads this average loss in power amounts to 40% or 50%, more or less, but is seldom as low as 35%. These are average losses and indicate the all day efficiency of the power transmission and distribution systems, and should not be confused with the loss at times of heavy load, or so-called *peak load*, on the power house, which latter loss is the amount by which the maximum power house output exceeds the sum total of the electric power taken simultaneously by the trains.

With the single phase and the three phase railroad systems the loss in electric power transmission and distribution is very much less than with direct current. On the large single phase installation of the New Haven road no transformer stations are used, as the current from the generators is conducted directly to the locomotives. The same thing is true in the single phase plant of the Grand Trunk Railroad at the Detroit River. The transmission and distribution losses at these places probably average less than 5% and even where transformer stations are used with single phase apparatus the losses are small, but are somewhat greater than 5%. The above statements about the efficiency of single phase distribution apply also to three phase distribution, but in a lesser degree because while both systems employ transformer stations without moving parts, three phase stations have to be closer together than single phase stations and consequently the transformer losses are greater in the aggregate.

#### EFFICIENCY OF THE THREE TYPES OF MOTORS COMPARED.

A comparison of the full load efficiency of the three kinds of motors show several percent, probably 3% to 4%, in favor of direct current and three phase motors compared with the single phase, and

this difference is increased 2% or 3% by the losses in the transformers used with single phase motors, but this difference is partly, or wholly, offset by the superior efficiency of the control of single phase motors which makes no use of resistances to cut down the current when starting and when running slow, as is done with direct current and three phase motors. In any event whether or not the lower full load efficiency of single phase motors and transformers as compared with other motors is entirely offset by difference in the efficiency of control, this difference in efficiency is very small compared with the difference in efficiency of the power transmission and distribution systems which is in favor of the single phase system as already described.

#### DIRECT CURRENT SUB-STATIONS, OPERATING AND MAINTENANCE COSTS.

There is one large item of operating labor and maintenance cost that must not be overlooked and which is necessary where heavy direct currents are used, but that has no counterpart in single phase and three phase operation. It is the attendance and repairs of the moving machinery in direct current sub-stations. This is a heavy expense, and for ordinary conditions will run between \$2000.00 and \$3000.00 per sub-station per year.

#### UNIFORM ELECTRIC RAILWAY SYSTEM.

Transportation constantly requires interchange of traffic between railroads, and this makes interchange of appliances and uniformity of systems highly desirable even if not absolutely essential. The use of special appliances to gain a slight advantage in some particular limited case will not be justified in railroad work, if a standard and uniform system can be found that will economically and satisfactorily meet all of the many demands on railroad motive power. A choice between the three existing systems should not be based upon consideration of those parts of the system in which there is no great difference in cost or efficiency or in their practical operation. It has been pointed out that (except in the matter of operating three phase motors) the difference in these regards between the three systems is not nearly so great in the power houses, or in the electric motors on the trains, as it is in the apparatus for the transmission and distribution of electric power from the power house to the trains. For ordinary railroad conditions the transmission and distribution apparatus is the most costly part of railroad electrification and is the part in which there is a vast difference between the different systems. If we could entirely eliminate the cost of this part together with the losses sustained in delivering electric power from the power house to moving trains, train propulsion with electric power would be so much more economical than with steam that steam locomotives would be supplanted by electric locomotives just as steam engines in industrial plants are being supplanted by electric motors receiving power from large central stations.

There is no present prospect of such a perfect wireless method of distributing electric power from power houses to railroad trains, but highly efficient and reasonably economical apparatus is available for the work.

THERE SHOULD BE AS LITTLE DEAD WEIGHT AS POSSIBLE ON THE  
WHEELS AND AXLES.

I will next mention a few important points to be considered in connection with electric locomotive designs.

You all know, in a general way, how the motors are mounted on the earlier designs of street-cars and interurban trolley-cars. Referring to the single reduction geared motors, the motor is suspended horizontally with one end carried on a bearing that rests on a car axle, and the other end is mounted with some form of spring-support resting on the truck-frame. This results practically in dividing the weight of the motor between two supports; one of the supports is the motor bearing on the axle, and the weight of the motor at this point is not spring-supported, so that any shock or blow, due to irregularities in the track or other causes, is transmitted directly to the heavy motor, and, conversely, whatever blow is transmitted to the motor is returned with equal force to the track, since for every action there is an equal reaction. It is obvious that the force of the blow struck will depend on the amount of the irregularity in the track, on the velocity with which the wheel strikes it, on the weight of the wheel and axle, and the weight that is attached inflexibly to the axle. Therefore, adding half of the weight of the motor to the axle in the manner just described increases the force of the blow of the wheels upon the rails. The other half of the motor, being carried on springs, rides easily on the track.

Consider for a moment the condition regarding weight on axles of steam-railroad rolling-stock. On steam locomotives the weight that bears upon the track without spring-supports intervening, is only the weight of the wheels, axles, and journals, since the weight of the locomotive-frame is carried by springs resting on the journals. Also there is some weight due to connecting rods which I will mention later, but the entire dead weight, or the weight that is not spring-supported in a steam locomotive, is a relatively small part of the total weight. The same is true of steam-railroad cars. All of the weight of the cars, excepting the wheels, axles, and journal boxes, is supported on springs.

Some people have had the impression that the most serious single cause for wear on steam-railroad tracks is the unbalancing due to the reciprocating motion of the locomotive cross-heads, connecting-rods, etc. This has always been balanced as far as possible, but it is not possible to completely balance it, and for this reason many people confidently expected that electric locomotives and motors which had no reciprocating parts would be far easier on the track than steam locomotives. The unbalanced effect of steam loco-

motive reciprocating parts is undoubtedly an important source of track-wear, but when the balancing is properly done this source of trouble can be very fairly well taken care of.

Experience with electric motor-cars and locomotives did not at first wholly fulfill the early hopes of electric motor advocates for railroad work. When heavy cars were operated at high speeds, it was found that the track-wear was much higher than anticipated, and it is evident that the dead weight of half of the motor on the axle is a very serious cause of increased track-wear, especially with high-speed trains. Some of the most skilled designers of electric locomotives and motor cars are strenuously discouraging the use of any construction for high speeds that adds dead weight (by which I mean weight that is not spring-supported) to the weight of the wheels and axles. There are two practical ways of avoiding this,—one method is called the quill suspension, the other is the side-rod construction to be described later on in connection with the electric locomotives of the Pennsylvania R. R. New York Terminal.

For the quill suspension, a tube or sleeve is placed around the axle between the wheels. The hole in the tube is considerably larger than the diameter of the axle. Flanged heads or arms are shrunk on to the ends of the tubes, and springs are inserted between the flanges or arms and the wheels so that the tube—or quill as it is called—is supported by springs with the shaft central through the hole in the tube. The springs permit a certain latitude of motion up and down and in a circular direction up to the limit of spring-compression or extension. In some recent designs of motors, the total clearance between the axle and the inner side of the tube is  $1\frac{1}{2}$  in. For gearless motors, the armature is built up on the tube—or quill—and the tube is the armature axle and runs in the motor bearings. The weight of the motor is balanced on springs, or on a frame that is supported on springs, the whole weight of the quill, the armature, and motor thus being spring-supported. With geared motors the gear is carried on the quill, as is also one end of the motor itself, thus securing a spring-support instead of making a dead weight on the axle.

This construction has been found very effective for relieving the force of the blow of the wheels when striking irregularities in the track, and effectively reduces the track-wear. The importance of having no dead weight carried on the axles increases as the operating-speed increases, and it is very essential at high speed. I believe that few people realize how essential it is until they learn from experience and observation. The pounding due to a reasonable amount of extra dead weight on the axle may not be serious to the track or the motors up to 35 miles per hour, more or less, but becomes very hard and must cause serious wear at speeds of 60 miles per hour or over, and where the dead weight is great it will be a serious factor at 50 miles per hour or over.

It does not require a very lengthy description to show how the

dead weight is relieved in the case of side-rod locomotives. In these locomotives the motor is mounted on the locomotive-frame, which is carried on springs which transmit the weight to the journal boxes. The power is transmitted through connecting-rods to a jack-shaft that has its bearings in the locomotive-frame, and from the jack-shaft it is transmitted again by connecting-rods to the driving-wheels. The connecting-rods, of course, require counter-balancing, and this is done for electric-locomotive connecting-rods more effectively than it can be done for the cross-heads and connecting-rods of steam-locomotives, since in the case of the electric-locomotives the motion of all the connecting-rods and journals, etc., is circular in direction, and a circular movement is possible of complete

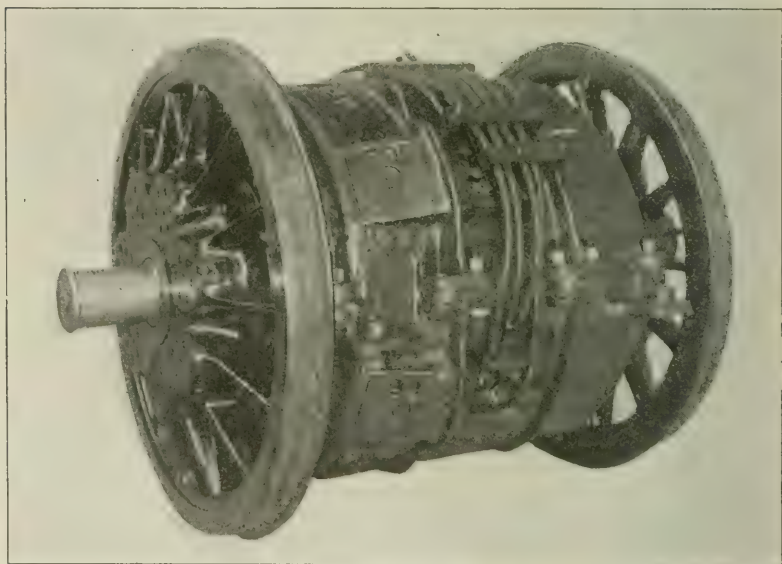


Fig. 7.—Single Phase, A. C. and D. C. Motor, Mounted on Locomotive Axle, Quill Suspension and Spring Drive to Main Driving Wheels.

balancing. In steam locomotives the motion of certain parts, like the cross-heads, is reciprocating and cannot be perfectly balanced. For this reason the balance of the connecting-rods on electric locomotives can be made more perfect than the balance of the connecting-rods and reciprocating-parts of steam locomotives.

THE CENTER OF GRAVITY OF LOCOMOTIVES SHOULD BE FAIRLY HIGH.

Regarding high and low centers of gravity in locomotives, experience has shown that locomotives, especially for high speed, should have the center of gravity high up. One of the reasons for this is apparent if we consider the effect of high speed on curved

tracks. Consider what would happen if a locomotive could be built with a center of gravity so low that it was directly between the rails and therefore on a level with them. Such a locomotive could be run at high speeds without danger of turning over on curves even on a flat track. Whatever other results might occur, the locomotive would not tend to tip over, but would press against the outside rail on the curve in a horizontal direction, and this would tend to push the rail over, and if the rail would not turn over, it would tend to push the whole track over—ties and all—and the whole track has actually been moved on curves by locomotives of very low center of gravity running at high speeds. Now consider the case of a locomotive with a high center of gravity. Such locomotives when run at high speeds on curves tend to turn over. This is countered by elevating the outer rail, but still the tendency to turn

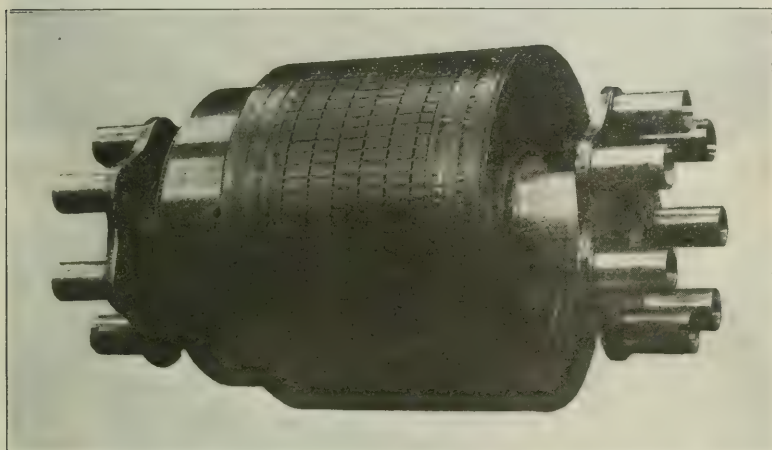


Fig. 8.—Armature of N. Y., N. H. & H. R. R., Single Phase, A. C. and D. C. Railway Motor, Showing Quill Construction.

over occurs on curves if the center of gravity is high, but with a high center of gravity the tendency to turn over throws the weight of the locomotive on top of the rail, pressing it down instead of pushing it out in a horizontal direction, as is the case where the center of gravity is low. It is manifest that a pressure on top of the rails will not spread the track or do the damage that a horizontal lateral pressure will cause.

The tendency of modern electric-locomotive design—especially for high speed operation—is toward a construction in which the dead or un-spring-supported weight of the wheels and axles is minimum and in which the center of gravity of the locomotive is high.

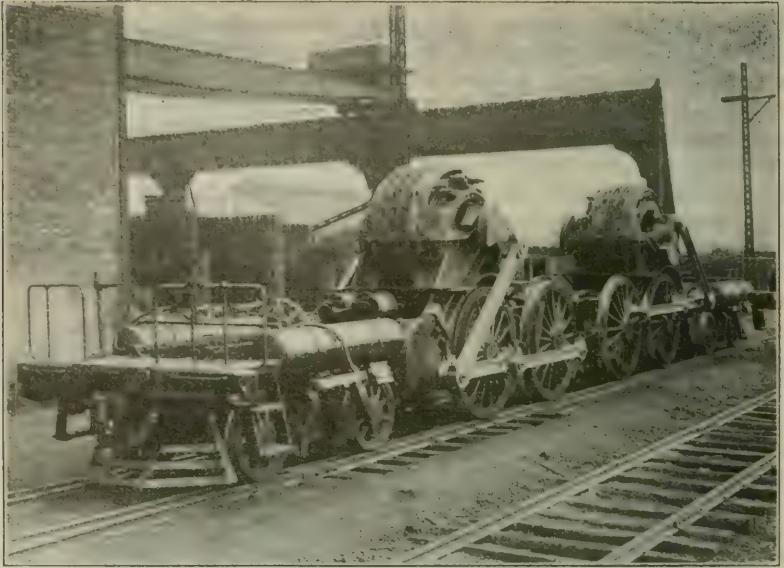


Fig. 9.—Pennsylvania R. R. Tunnel Locomotive (Cab Removed), Showing Mechanical Parts and Side Rods.



Fig. 10.—Pennsylvania T. and T. Co., D. C. Electric Locomotive, New York and Jersey City Tunnel Service.

## GEARED VERSUS SIDE-ROD LOCOMOTIVES.

There has been considerable speculation and controversy regarding the relative merits of geared locomotives and side-rod locomotives for powerful machines. The New York, New Haven & Hartford Railroad Co. is going to determine this matter in a practical way. It has contracted for two very powerful moderate speed locomotives to perform equivalent work. One of these locomotives is already built and is in operation with gears. The other one is being built with side rods. The motors of the geared locomotive drive through quills, so that they add no dead weight to the axles and they are carried vertically above the axles instead of in the customary horizontal position, and therefore the motors are easily accessible and the center of gravity is higher than it would be if they were horizontal.

## DISCUSSION.

*Mr. G. T. Seely*, M. W. S. E. (Chairman): The speaker gave a correct statement as to the saving in the operation of steam railroads by the adoption of electricity, and a case in point was the saving which was accomplished on the South Side Elevated Railroad when it commenced operating by electricity. The conditions are not exactly the same as in heavy steam-railroad work but still there is some similarity. The South Side Elevated Railroad was operated, in the beginning, with steam locomotives, propelling trains of two to five cars. In 1896 or 1897 it was one of the first roads operating *trains* of cars to adopt electric propulsion. At that time we were burning, in the day time, anthracite coal to prevent smoke. At night when the eye of the smoke inspector was a little dim we would mix in some bituminous coal; not because we wanted to get ahead of the smoke department, but because of the financial condition of the road, then in the hands of a receiver. Our coal cost on an average about \$4.00 to \$5.00 per ton. When electricity was adopted the amount of coal burned in the power-house was less in tonnage than the coal burned in the locomotives, and the cost, instead of being from \$4.00 to \$5.00 was less than \$1.50 per ton. When burning 150 tons of coal a day it will be seen that a great saving was effected by the adoption of electricity. A saving was also made in the wages of the trainmen, but that would not be the case on steam railroads.

The cost per car mile of conducting transportation was reduced over one-third by the adoption of electricity over operation with the steam locomotives. The saving was a very considerable one and practically put the road on its feet.

*Mr. W. L. Abbott*, M. W. S. E.: I was much interested in some of the figures which were given, showing the distribution of the investment between the different parts of the standard electrical equipment of the road,—one-third to one-fourth to the power-house,

about one-half for the distribution system, and the remainder for the equipment on the moving train. The fact at once becomes prominent that if, with existing systems, one-half of the entire equipment-cost of a road is required for the distributing-system and the moving machinery in substations, the advent of a new system which will greatly reduce the weight of copper required and eliminate entirely the moving apparatus in the substations must be an advent in electric railroading, whose effect will be noticeable in the near future wherever electric roads reach out and parallel steam roads. Those of us who are not in the railway business—either steam or electric—have been wondering at the apparent indifference with which the steam-road owners view the paralleling of their lines by electric roads. They affect to say that the electric road is merely developing a class of business which they—the steam roads—do not care to bother with, and that when the electric road grows to be of some importance they will buy it up and annex it. Such benevolent assimilation was recently witnessed in the case of the Western Union Telegraph Co. buying out the telephone company. The scheme worked the other way.

With the general adoption of high-tension distribution, feeding a great system of interconnected railroads, we can conceive of power-houses located at strategic points, such as coal mines and water powers, thus relieving the steam roads of the necessity of buying high grade coal and of hauling it to their coaling points. The possible saving of the cost of hauling locomotive coal taken in connection with the higher efficiency of a power-house on a concrete foundation as compared with one on wheels, is enough to make the difference between running a railroad at a profit and running it into the hands of a receiver. I believe it is regarded as inevitable, even by those who now operate steam roads, that all roads in territories where the traffic is as dense as it is within several hundred miles of Chicago must, within a comparatively short time, be operated by electricity, and from power-houses so widely separated that it will be necessary to use on the trolley wire higher voltages than are permissible within the city limits.

*Mr. W. B. Jackson, M. W. S. E.:* I have listened with much interest to this paper, as the matter of alternating-current traction vs. direct-current traction, which is in a way embodied in this paper, is unusually interesting, owing to the fact that eight years ago (I think it was) the Valtellina road that has been referred to in the paper was just starting. I had occasion to go over that road with considerable care. It is a three-phase road with cascade operation, and although the company that put in the equipment was having its troubles on account of its being quite a novel installation, yet it was one of the most perfectly operating roads that I think I was ever on as regards the starting and the stopping of trains. It seems to me that by no means should we feel that the last has been said about the possibilities of the three-phase traction. We have heard

that the transmission system is a very important factor of alternating-current or direct-current railroads, and as our main-line railroads become electrically operated, the transmission system will become more and more important, owing to the very large quantities of power that must be transmitted great distances. In the case of the three-phase roads, we have the standard three-phase transmission, while with the single-phase roads we have the single-phase transmission. Also, as regards substations, it does not seem that there should be much difference between the three-phase and the single-phase, in that very large high-voltage three-phase transformers can be constructed, I believe, at not greatly increased cost over single-phase transformers. The distribution to the trains, although it may be necessary to use a lower potential, is on the three-phase basis and operates motors of the most reliable and satisfactory character which may be worked so as to be regenerative, although in the case of the Northern Pacific installation, which has been referred to, I believe the regenerative feature is obtained merely by operating the locomotives at a greater speed down-grade than their normal speed up-grade; consequently only a small part of the advantages of the regenerative feature is obtained in this installation. But it is entirely practicable to arrange installations so that the regenerative feature may be taken advantage of at all speeds above half-speed, and for all speeds above one-fourth speed, if the complications incident to such arrangement can be overcome suitably, so that breaking, at least down to half-speed, can be accomplished very well indeed by returning current to the trolley with the accompanying saving in power. When trains are slowed down to half-speed by returning power to the trolley, assuming appropriate equipment, it is almost impossible to tell just when the train is slowing down except when standing up in the car so that the reduction in speed may be felt through inertia. All things considered, I am not at all certain but that three-phase traction may eventually work in as a far more important element in long-distance railroading than present conditions indicate.

*Mr. A. P. Jenks:* I do not know that I should consider myself qualified to discuss Mr. Darlington's very interesting paper, as my work for the past few years has been more along commercial lines than engineering; at the same time I have tried to keep up-to-date in electric railway development as to both high-tension alternating-current and direct-current systems. As pointed out in Mr. Darlington's paper, the respective systems have their strong advocates, and probably always will as long as they exist, and I judge from Mr. Darlington's talk and his paper that he is one of the strong advocates of the single-phase system and has rather neglected the high-tension D. C. system. I desire to take exception to a few of his statements in comparing the single-phase high-tension system with the direct-current. I believe he states in his paper, which I have not carefully read, that the initial cost of the single-phase is far

cheaper than either the 600 or 1200 volt D. C. systems. Of course, local conditions have to be taken into consideration and that is a rather broad statement to make. It may be true under certain conditions. Under other conditions the reverse would be very likely true. I think, for comparatively short roads operating a large number of cars with frequent service, that the 600 volt D. C. system will give a lower first cost than the single-phase system. I have recently seen a number of very interesting engineer's reports, carefully prepared, showing that the 1200 volt D. C. system is just as cheap in first cost as the single-phase 6600 volt system for what you could call interurban roads in length from 25 to 50 or 75 miles. As Mr. Darlington states, the difference in cost between the single-phase and the direct-current, presumably on the basis of 600 volts D. C., is largely in the distribution system, being in favor, of course, of the single-phase, but that difference, when the voltage is raised to 1200 or higher, disappears almost entirely in the cost of the overhead copper. We then have the excessive cost of the very expensive single-phase motor-equipment compared with the extra cost of the direct-current rotary-converter substations, and I think it will be found for the average interurban railway that these two items will about offset each other, leaving an even balance for the total initial investment.

With reference to the operating cost, again Mr. Darlington infers that the single-phase system is much cheaper than the direct-current system, due to the absence of substations in the former system. That is true to the extent that they have not that expense. But on the other hand, it has been shown—and I have seen reliable data obtained from roads that have operated with both single-phase and 1200 volt D. C.—that the maintenance cost of the single-phase motor-equipment is much higher than the direct-current equipment, which more than offsets the extra expense of substation maintenance, and there are other important factors that make the 1200 volt D. C. system much more attractive from an operating point of view.

I am not bringing out these points in the nature of a criticism of the single-phase system because I believe that the single-phase system has its merits, but I also think that the high-voltage D. C. system, which has been developed since the single-phase was brought out, is coming to the front rapidly—is here, in fact—as there are a dozen or more roads now operating with this system. It has the advantage of the low initial cost of the single-phase and none of the latter disadvantages as applied to the average interurban trolley road.

Trunk-line steam-railway service is a different condition and must be studied carefully. I think the possibilities of higher direct-current voltage—1800 to 2400 volts—will probably put it on an equal basis with the 11,000 volt single-phase system.

Another point that I wish to bring out is that the 1200 volt.

D. C. system permits of using standard D. C. apparatus. The railway motors are either standard 600 volt motors, insulated for 1200 volts, or wound for 1200 volts, which is made possible by the introduction of the commutating pole motor; 600 volt 25 or 60 cycle rotary-converters can be run in series, or built for 1200 volts, and there is no difference in the operation of the high-voltage D. C. system and the so-called standard 600 volt system. The simplicity and familiarity with such a system is a very important factor in its favor, I should think, from an operating standpoint, and furthermore, it enables the railroad companies to utilize 25 cycle or 60 cycle current, with the resultant advantage of being able to furnish power for lighting or industrial purposes. To get the full benefit of the single-phase equipment, it is necessary to go to lower frequencies, such as 15 cycle, which would mean special apparatus throughout.

*Mr. A. Bement, M. W. S. E.:* I have a word to say. It is relative to the appreciation shown by the public for electric service, which includes electric transportation service. I think it is a very important factor, but I do not think an attempt has been made to determine a value for it, but it has, I consider, a large value. We see this illustrated in the case of trolley lines that parallel steam railroads. They take from the steam railroad a large part of the business which formerly waited for the arrival of the steam trains; they also take another large percentage of the business from the steam trains, even when the steam trains are waiting to take the passengers. This is well illustrated in the vicinity of San Francisco. Communication across the bay from San Francisco to Oakland, Berkeley, and Alameda is by ferry. There are two transportation lines,—the Southern Pacific with steam service, and the San Francisco, Oakland, and San Jose, which is an electric line. These lines parallel each other as to accessibility, frequency of trains, and in all other respects they are in duplicate, except that one is operated by steam and the other by electricity. They gather their passengers in the same manner and deliver them at the head of long piers, from which point they go by ferry-boat across the bay to San Francisco, all arriving at the same ferry-house. Likewise, in leaving the city, passengers leave from the Market Street ferry for their homes in the cities across the bay. In fact, in one respect the Southern Pacific has an advantage over the electric line, as its ferry-boats are equipped with a restaurant, while boats of the electric line are not. Notwithstanding the fact that the service afforded by the steam line could be considered equal to that offered by the electric line, the latter trains handle practically all of the suburban passenger traffic up to a point where the congestion on the electric line causes an overflow to go to the steam trains. The Southern Pacific Railway is planning now to electrify its suburban service so that it may compete with the San Francisco, Oakland, and San Jose Railway, which is popularly known as the Key Route.

In reference to the low center of gravity in locomotives, in addition to its tendency to exert a force on the rail tending to push it out of place, it causes excessive wear of both wheel flanges and rail heads.

*Mr. E. N. Lake, M. W. S. E.:* I would call attention briefly to two subjects which to my mind have not received, in the paper of the evening, the attention which it seems to me their importance requires. These are *standardization* and *interchange*. Let us think for a moment of the steam-road engineer who approaches this question of electrification. He sees in the printed paper here the simple statement that there are three systems of electrification,—the direct-current, the single-phase, and the three-phase. But from the standpoint of interchange instead of three systems, let us see how many there are. You may subdivide the direct-current system into the principal divisions of 600 volt and 1200 volt. You may further subdivide the system as to working conductor into an overhead trolley and the third rail. Then there is the modification of gearless and geared motors, connecting-rods, and all that class of variation in design, all of which affect clearance, presumably. Then when we take up the single-phase system and consider, say, fifty-four existing railroads which have a mileage of 1700 or 1800, and a total motor horse-power of say 200,000, about equally distributed as to number of roads between America and European countries, we find that there are a large number of variations in this system. For instance, we notice that in our own country there is a difference in the matter of catenary, single-catenary, and double-catenary. There are at present seventeen different voltages in operation on single-phase systems, ranging from 500 volts to 20,000 volts. Some railroads have two or three voltages on the same system. There are seven different frequencies in operation at the present time, ranging from 15 cycles to 42 cycles, so that, as a matter of fact, from the standpoint of interchange instead of three systems there are nearly thirty-three. These questions of standardization and interchange must be worked out, must be reduced to their simplest terms, before we can expect that electrification will make its strongest appeal to the steam railroad people. The history of railroad development has been first the development of isolated lines and systems. Electrification seems to be following along the same path. We have isolated electrification systems for city terminals, at tunnels, and at such locations as that; but electrification will never make its appeal to the trunk-line proper until these questions of interchange and standardization have been worked out.

There is one question I would like to ask and that is as to a new design of the catenary construction,—what the working conductor would be, whether it would be part copper and part steel wire, or all copper or all steel.

*Mr. Seely:* A point in favor of these different systems is the fact that we have them, and the enthusiastic supporters of each

system brings about an advance in the art; with the present state of the art, if we did not have this competition there would not be as much advance made.

*Mr. George H. Lukes, M. W. S. E.:* One thing occurred to me in listening to Mr. Darlington's paper, and that is the difference in the attitude. This perhaps illustrates the progress of electrification of steam-railroads. Several years ago we had a meeting which was addressed by a prominent engineer from one of the manufacturing companies, on the electrification of steam-railroads, and, as I remember it, throughout his talk he was very careful to say that electrification was applicable to special conditions only. He was very careful not to say it was applicable to all conditions. He spoke about electrifying certain divisions on trunk lines—mountain divisions where the traffic had outgrown the capacity of the steam equipment. Tonight I notice that Mr. Darlington does not seem to be at all alarmed at the idea of electrifying ordinary steam railroads, which I think illustrates that there has certainly been a great advance in the last two or three years.

*Mr. C. Renshaw:* The author states in his paper—and it seems to be the keynote of the matter in regulating the discussion—that it was not his object to bring out the desirability or the economy of electrification as compared to steam, but to present the problem as to which of a number of available systems was most suitable to the general problem of electrifying steam railroads.

The Baltimore tunnel was equipped with electric locomotives in 1893. As far as the locomotives alone were concerned, engineers were entirely capable of electrifying steam railroads at that time, but no such electrification was then undertaken other than that of tunnels or terminals, because, although motors were then available, a suitable transmission system was lacking. For the same general reason trolley roads were built paralleling steam lines all over the country rather than the electrification of the steam lines themselves taking place. The men in charge of the steam railroads felt that the electric system—particularly the transmission system—that was available was not suitable to their conditions. They could have electrified their lines and operated over them single cars, light cars, of the same character that were used by the trolley roads which paralleled them, but they all seemed to feel that this was not the solution of their problem. Any system of that nature which they might put into operation would be temporary and would sooner or later have to be replaced with a system which could handle not only single-car operation but train operation; which could handle not only a passenger but also a freight business; and it was not until the development of the alternating-current systems that any system was made available for the use of the steam railroads which enabled them to electrify their lines on a permanent basis. The development of the high-tension alternating-current system has now brought about that condition, and electrification has reached a point

where any steam road can electrify any length of line that it sees fit; not merely a tunnel, or a terminal, or a short stretch where suburban travel is heavy, but any portion of the road; any length of line that seems desirable can be electrified on a basis which will enable it to handle any kind of traffic that steam-power can handle, and to do so with a reasonable investment as far as first cost is concerned and with a reasonable operating expense.

The original electrification of trolley roads required the construction of a power-house and of the trolley line; also the purchase of some cars to run over that line. The power-house was able to feed the entire system directly without any intermediate link. Now, for ordinary distances the single-phase system has put the steam railroad on exactly the same basis. By the use of 11,000 volts on the trolley, a steam railroad can electrify a reasonable distance and simply feed from the power-house, directly into the trolley line, with no other link between the generation of power and its utilization at the car. The electrified portion of the New York, New Haven, and Hartford Railroad, for instance, is operated in this way. It consists of a stretch of 22 miles and the entire 22 miles is fed in the simple, old-fashioned way of the trolley road. The generators are connected directly to the trolley wire, and the latter supplies the locomotive.

By simple extension, the 22 miles could be easily extended for three times its present distance with essentially the same simplicity. Two transformer-stations located 30 miles each way from the power-house could each supply a 22 mile section (no attendants would be necessary at the transformer stations or anything of that sort) and 66 miles could thus be operated with the same general simplicity as the present 22 miles is operated.

In a certain way it may be said that a three-phase system would offer equal facility for electrification, were it not for the fact that the three-phase system requires a distributing-system, as Mr. Darlington brings out, which is very much more complicated than the single-phase; it requires substations oftener than the single-phase, and requires these substations to be more complicated; in general, it runs up complications of that sort so much, that except for special service it hardly seems desirable.

The matter of interchange of equipment and standardization, which one of the previous speakers called attention to as being a vital point as far as steam railroads are concerned, can be solved at once by the 15 cycle, 11,000 volt, alternating-current system. As far as any question of satisfactory operation and features of that sort are concerned, such a system could be adopted today and be adopted as an absolute standard. Any railroad in the country can electrify its lines with this system, and be absolutely sure that the system can be extended indefinitely to cover any kind of steam railroad service that is in operation today.

It is true, as one of the speakers has said, that the single-phase

roads that have been put in, considering the trolley roads also, have been put in with a wide range of voltages and with a slight range in frequencies, but considering the steam railroad electrifications proper, the range has not been nearly so great. Three different steam-railroad electrifications have been put in on exactly the same basis. The New Haven Railroad has been put in with 25 cycle, 11,000 volts. (This is the largest and most important.) The Erie Railroad (a portion of it) has been put in on the same basis,—11,000 volts and 25 cycles. The Denver and Interurban road, which is an electrification of the Colorado Southern, was put in on exactly the same basis—11,000 volts and 25 cycles—and, in general, these conditions have been to a certain extent standardized at the present time for steam-railroad electrifications. What has been done in the way of electrification now, however, is only a drop in the bucket, and it has become evident that in looking forward to electrification on a large scale, 15 cycles at the same tension of 11,000 volts has some advantages over 25 cycles, but as far as this matter is concerned, 25 cycles would give an entirely practicable system; the steam-railroads of the country could be economically and satisfactorily electrified today with this one particular system that has been put in service, if necessary, and every kind of traffic that is handled today by the steam locomotives could be handled in this way.

The reasons which make the single-phase system so satisfactory are of course familiar, in a general way, to all, but possibly by quoting a figure or two I can bring out the vital point in a way which will be more likely to be remembered.

If we consider an ordinary trolley construction of single track, 70 pound rails, and 000 trolley wire, for direct-current, there will be a drop in voltage of about 33 volts per 100 amperes per mile. If one undertook to transmit 100 amperes for 10 miles over such a line, there would be a drop of 330 volts, and if the line was being supplied at 600 volts, there would be left 270 volts at the distant end of the line, which, with 100 amperes, would mean 27 kilowatts. It would also mean that there was a loss of 55%. But in transmitting power with 25 cycle alternating current, at 11,000 volts, over the same circuit there would be a drop in voltage of 60 volts per 100 amperes per mile, and an energy loss of about 60% of that, or 36 volts, and in transmitting the same current of 100 amperes for 10 miles there would be 600 volts drop and a loss in actual energy corresponding to 360 volts lost. That 600 volts drop in this case, however, with 11,000 volts supplying the line, instead of being 55% drop would be only 5.5% drop, which would be entirely insignificant as compared with the drop in the other case. Moreover, supplying 100 amperes at 11,000 volts, 1040 kilowatts would be transmitted instead of 27. In this way a startling difference will be noted between using 11,000 volts on a trolley line in transmitting power, as compared with using 600 volts or even 1200 volts.

From the same figures it can be seen that one may transmit power at 11,000 volts for 100 miles with only the same percentage drop which was obtained in transmitting 10 miles with 600 volts.

One significant fact has impressed me very greatly in considering the matter of real trunk-line electrification. Practically the only real trunk-line electrification that has been put into effect, where any length of railroad has been electrified for other purposes than the mere carrying of trains through a tunnel or handling a strictly suburban traffic, is that of the New Haven road. Of course, the suburban traffic of the New Haven road is fairly heavy, but there are a large number of other trains handled over that section also. This one trunk-line which has been electrified on a large scale with the single-phase system is the only trunk-line which, after having been electrified, has been so satisfactory that the management has considered extending the electrification. The New York Central R. R., which is often compared with the New Haven system, is only just now completing the plans originally made for electrification, and, as far as has been published, no intimation has been made that they would ever carry that electrification to any point beyond the limits originally laid out.

The New Haven road, on the other hand, is making active plans to carry its electrification further, and to carry it the whole distance from New York to New Haven. This would considerably more than double the portion of the line which is now operating electrically. As showing the interest that the New Haven road is taking in this matter, they have since equipped an additional mile of road with a slightly different form of catenary trolley construction—a somewhat cheaper form—which was worked out as being the proper kind of construction to use when they did carry their line on to New Haven, and they put up this mile of it, in order to see how it would work out in actual practice, and to get ready for quickly carrying the work further in the near future, when the time seems ripe. They have also been making very careful study with regard to operating their freight trains electrically, and the Westinghouse Electric and Manufacturing Co. is supplying to them two different types of electric freight-locomotives. Each of these is capable of handling a 1500-ton freight-train, which is as heavy a train as is ever operated over their road. One of these locomotives has been tested at the works, and has been tested on the New Haven road, and has actually handled a 2200-ton train, starting it up from rest and pulling it out of a siding, which had a very sharp curve leading into the main track. It is a most impressive sight to see an electric locomotive take hold of a train of this sort—so long a train that it is quite a task to walk to the end of it—and pull it along, quietly and easily, with the sole source of its power from a little wire hardly any thicker than a man's finger. To see that done is one of the most convincing arguments that can be presented in favor of the high-voltage, alternating-current, single-phase system.

An incidental, but nevertheless an important advantage of the single-phase system is the fact that on account of the long distance over which power can be transmitted at high voltage, a single unit—either a power station unit or a substation unit—can handle a much longer stretch of track than could otherwise be handled, and consequently with trains widely scattered this unit can be kept more uniformly loaded. If a certain substation can cover only a limited section of track, then of course that unit is going to be running a much greater part of the time at light load than would be the case if it should cover a longer section of the track, because, regardless of the character of the service, it is only reasonable that the longer the section of track considered the more uniform will be the load on that section.

The single-phase system is able to handle any kind of traffic that the steam locomotive can handle. This will enable the railroads to carry out electrification in piecemeal if they desire, and yet have something permanent when they get through with their work. For instance, a terminal line of twelve or fourteen or twenty miles or so can be electrified for immediate use in handling suburban traffic. The same system can handle freight traffic over that section, or can handle heavy through-trains over that section, with equal facility, and consequently all trains running over the section for any purpose can be readily handled by the system which is installed. If a direct-current system were put in, although it might be admirable for handling the suburban service, it would be at a disadvantage in handling the heavy-train service and would be at a most decided disadvantage if it were necessary to add a more distant link in connection with it.

With reference to the matter that one of the speakers brought up, considering, of course, trolley roads rather than steam railroad electrification, since there has been no steam-railroad electrification using 1200 volts direct-current, it is hardly proper to speak of 1200 volt apparatus as being absolutely standard, because, although 1200 volt equipments can be run on 600 volts, 600 volt apparatus of the ordinary sort most certainly can not be run over the 1200 volt lines. Better insulation is required for 1200 volt apparatus, and to secure room for this a motor of a given horse-power capacity for operation on 1200 volts takes, ordinarily, the next larger size of frame than is required for 600 volts. The control apparatus also has to be better insulated and laid out for 1200 volt work.

In regard to the cost of maintenance being high on single-phase apparatus, this is not necessarily the case. The speaker may, of course, have gotten his figures from specific instances where the cost was high; but to show that the cost is not necessarily high, I might say that I had occasion to go over the books of one of the largest single-phase trolley companies—and one of the first ones also, for that matter—the Indianapolis & Cincinnati Traction Co., and in going over their books very carefully for the year 1908 it

developed that the cost of maintaining the electrical equipment of the cars was less than is the cost on a great many direct-current roads. Actually, it figured out something less than 0.75c per car mile. I have known of 600 volt, direct-current roads operating on a basis that was fairly comparable with this single-phase road, in which the maintenance of electrical equipment cost considerably more than this figure.

In regard to the matter of using 60 cycle current for conversion into 1200 volt direct-current, it is, of course, just as easy to convert 60 cycle current into 15 cycles or 25 cycles by means of a motor-generator set as it is to convert it into direct-current, especially into 1200 volt direct-current, for although one might use 60 cycle rotary-converters for converting 60 cycles into 600 volt direct-current, I have never heard it proposed to connect 60 cycle rotaries in series for producing 1200 volts. Even if this should be done, a great many people, particularly on the Pacific Coast where 60 cycles is prevalent, use motor-generator sets even for obtaining 600 volt direct-current for railway work, and they consequently could just as well obtain 25 cycle or 15 cycle alternating-current in the same way as they obtain direct-current of either kind.

*Mr. G. W. Brady, M. W. S. E.:* I wish to ask if the New Haven road is still operating the third-rail branch they used to have some years ago, and also what the power-factor was on the A. C. line where this compensating winding in the single-phase motor is being used.

#### CLOSURE.

*Mr. Darlington:* I am very much gratified with the general agreement with what I have said, and am glad that two or three points have been brought out which I deem of equal importance to anything that I have said.

I am going to speak of these questions in the reverse order to that in which they were brought up.

The power-factor on the New Haven road on the alternating system with 25 cycles is not so good as it would be with 15 cycles. It ranges generally between 80% and 85%. Of course, the power-factor is not a very important item. A lower power-factor simply means that the transmission lines and trolleys, etc., should be slightly larger. The size of these is largely a question of voltage.

Somebody asked whether with new construction steel or copper would be used for the contact wire. I think there is no objection whatever to running on a copper wire unless one is running at very high speeds, where there is liability of breaking the contact wire at the point of support. Copper is perfectly proper up to fifty or sixty miles an hour, and steel would be unnecessary for lower speeds.

The question of standardization and popularization of railroad service by electrification are both matters of prime importance. I did not mention them because I could not cover the whole

field. We all appreciate that if the railroads of the country are going to be electrified generally, there must be a standard system just as a standard track-gauge is needed for all railroads. They will all have to use one electrical system just as they all have to have a uniform track-gauge. The popularity of electric power is one of the great things that has led to the development of trolley-road service. People prefer to ride on electric roads wherever trolley roads are available, not only because it is nicer on the cars, but also because trolleys stop on the street corners, run over the city streets and take them where they want to go,—all of which features operate in their favor.

One of the speakers evidently misunderstood the purpose of my paper, for he has overlooked in his discussion the features that I tried to bring before you. The matter of 1200 volts versus single-phase has been much discussed, but 1200 volts has been talked of almost entirely as applied to trolley roads. I have been trying to talk to you about the electrification of existing steam railroads, not trolley roads for operating a single car or for operating at most two or three cars on a uniformly distributed schedule. Wherever 1200 volts has been used it has been on trolley roads. I have tried to avoid talking about what may hereafter be done with electric power, except where practical applications have demonstrated the results that may be secured with direct-current, or with three-phase current, or with single-phase current. There are no heavy railroad electrifications with direct-current except at terminals and for short distances. Ordinary railroad trains are heavy trains; they are generally more than two or three car trains and they are not distributed on even schedules half hourly or hourly, as is customary with trolley roads.

A very excellent paper was published by Mr. C. E. Eveleth in the transactions of the Philadelphia Branch, A. I. E. E., on the 1200 volt interurban railways, in which is given the cost of 1200 volt electrification, but Mr. Eveleth gives the cost of 1200 volt electrification only for light railroad service, the heaviest being for three-car trains, on an evenly distributed service. That means 1200 volt costs are estimated by Mr. Eveleth for trolley roads operating three-car trains. When his figures are examined it will be found that they give the total cost of power transmission and distribution apparatus for 1200 volts, including the transmission line, the substations, and the third-rail, but without third-rail feeder of copper wire, close to \$14,000 per mile of single track. If one were to electrify with 1200 volts for heavy railroad service, the cost based on those calculations would go still higher—to \$15,000 or \$20,000 a mile without any question—and these are the best figures I know of that have been published. We cannot put such a tax on the steam railroads and expect the savings by electrical operation to pay interest, operating-expenses, and fixed charges on the electrical equipment. Furthermore, say what you will about 1200 volts, there

is still the substation operating-expense which is a heavy cost that is not required for alternating-current traction. In standardizing, there must be something that will do not only for the trolley roads but for steam railroad electrification, and something that will not cost \$14,000 or more per mile for apparatus to get the current from the power-house to the moving trains.

In the matter of the power plant. That is a very interesting subject and one I would like to talk about, but will say only this: When railroad electrification gets to be general, it will start in fairly populous districts, and without any question economy of operation and construction will determine that the power-plants will be, as Mr. Abbott said, at strategic centers, in places where a power-plant can be built to serve a large number of trains, a long mileage of track, utilize cheap coal, and secure a fairly even load-factor by distributing electric power to a large number of trains. I predict when railroad electrification gets to be general in this state of Illinois, there will be three or four big power centers in the state that will be selling power to railways, and big electric power-plants will be built that will furnish power over a great many miles, and sell power to different railroads and also to all sorts of manufacturing and industrial enterprises.

Referring now to Mr. Jackson's remarks, it is true, as he remarked, the last has not been said about three-phase traction. There are places where three-phase current has advantages. A bad thing against it, however, is the question of standardization. In order to make the three-phase system generally acceptable it must be capable of being standardized. To be standardized it must be suitable for high speeds; it must be suitable for low speeds; and for frequent starting, stopping, and accelerating, and most of all it must be economical. Three-phase installations do not meet all of these conditions as well as single-phase for average railroad requirements.

Mr. Jackson spoke of a trolley road in Europe which has three economical operating-speeds. How do they get them? They have a motor for one speed; at another speed they have another motor, and at another speed they put the two in together. That is not an economical condition.

I take exception to Mr. Jackson's statement that three-phase transformers can be built as cheaply as the single-phase. In general a three-phase transformer is more costly than a single-phase transformer of the same capacity, and this is especially true in the case of very high voltages. The winding of a transformer goes up in cost very rapidly as the voltage increases, and the winding of three-phase transformers is more costly than for a single-phase transformer of the same total capacity. Railroad electrification is a question of getting a system that is suitable for standardization for all kinds of work, keeping the point of economy in view.

# RESCUE STATIONS IN ILLINOIS COAL MINING LOCALITIES.

BY R. Y. WILLIAMS, M. W. S. E.

*Presented May 4, 1910.*

## Introduction:

- a. Importance of Illinois as a coal producing state.
- b. Frequency of mine fires and explosions.
- c. The rescue station at Urbana, Illinois.
- d. The need of additional rescue stations throughout the state.
- e. Definition of a joint rescue station.

I. The Design and Equipment of a Joint Rescue Station.

II. The Character of the Training given in a Rescue Station.

III. The General Advantages to be Derived from Rescue Stations:

- a. Any problem may be attacked immediately and safely.
- b. Training induces discipline.
- c. The stations are educational centers.

IV. A General Plan for Rescue Stations in Illinois.

## INTRODUCTION.

The discussion of any problem affecting coal mining methods applicable to such a state as Illinois is of considerable interest, because Illinois stands second in the list of the twenty-seven coal-producing states, and holds in reserve more bituminous coal than any other state in the Union. It is also the second largest producer of bituminous coal. This position, however, has been attained by the sacrifice of many human lives and the loss of millions of tons of coal. The indefinite continuance of these conditions would be most unfortunate. But coal mining engineers are facing these problems seriously. Already the explosiveness of coal-dust has been demonstrated, methods of its control investigated, a list of permissible explosives has been published by the government, and a paper on some phase of the efforts now being made for the conservation of that greatest of all natural resources, human life, it is believed will be of value.

The investigations in this field are proceeding along two lines—the prevention of mine accidents and the work of mine rescue. While the first is by far the more important problem,

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it is nevertheless apparent that calamities such as mine explosions and fires are of such frequent occurrence as to be a constant menace to the safety of the man and of the mine. For these reasons the work of rescuing life and saving of property are urgent problems in present-day coal mining. With this in mind, the following has been written in an endeavor to present a general scheme for Joint Mine Rescue Stations in Illinois.

Early in March, 1909, the United States Geological Survey, in co-operation with the State Geological Survey and the University of Illinois, established at Urbana, Illinois, a mine rescue investigation station which is a branch of the Central Testing Station at Pittsburg, Pa. This sub-station is equipped with oxygen helmets and has a gas-tight room resembling a coal mine, in which miners may test the efficiency of modern breathing appliances. Already this mine rescue laboratory has been visited by many operators and inspectors; a large number of miners have been trained in the theory and practice of rescue work; and considerable assistance has been given on the occasion of several mine fires and explosions. One station, however, cannot render adequate service in a state having more than 400 large shipping mines scattered throughout an area of 275 by 180 miles. In fact, it was not the intention to establish at the Urbana station a permanent rescue corps to act in the event of mine disasters in ordinary rescue work. This station was established primarily to supply the equipment and trained assistants required for the study by the Survey experts of mine explosions in the Illinois-Indiana-West Kentucky coal field, and in the hope that the station would offer a means of demonstrating modern mine rescue practice to the mining fraternity of this field.

When an explosion or fire occurs in a coal mine, conditions are usually such as to require that the men entering the mine be protected by helmets, which must be supplied as quickly as possible. It is, therefore, necessary, both for rescue and investigation work, that stations should be within easy reach of each important coal field or division of the field, so that the trained experts can reach and enter the mine promptly following the disaster. Were each mine in the state equipped with a complete rescue station and manned with a corps of trained rescuers, we would have ideal conditions for the recovery of life and preservation of property after a calamity. But, unfortunately, these stations are quite expensive; equally unfortunate, the present selling price of coal is so low that the small margin of profit is already a matter of much concern, so, unless some remedy for this condition can be found, but few individual mine owners, I fear, would feel warranted in authorizing such an expenditure of money. In order to overcome this obstacle and

still obtain the benefits of modern mine rescue methods, the suggestion of joint rescue stations, it is believed, should be of great value.

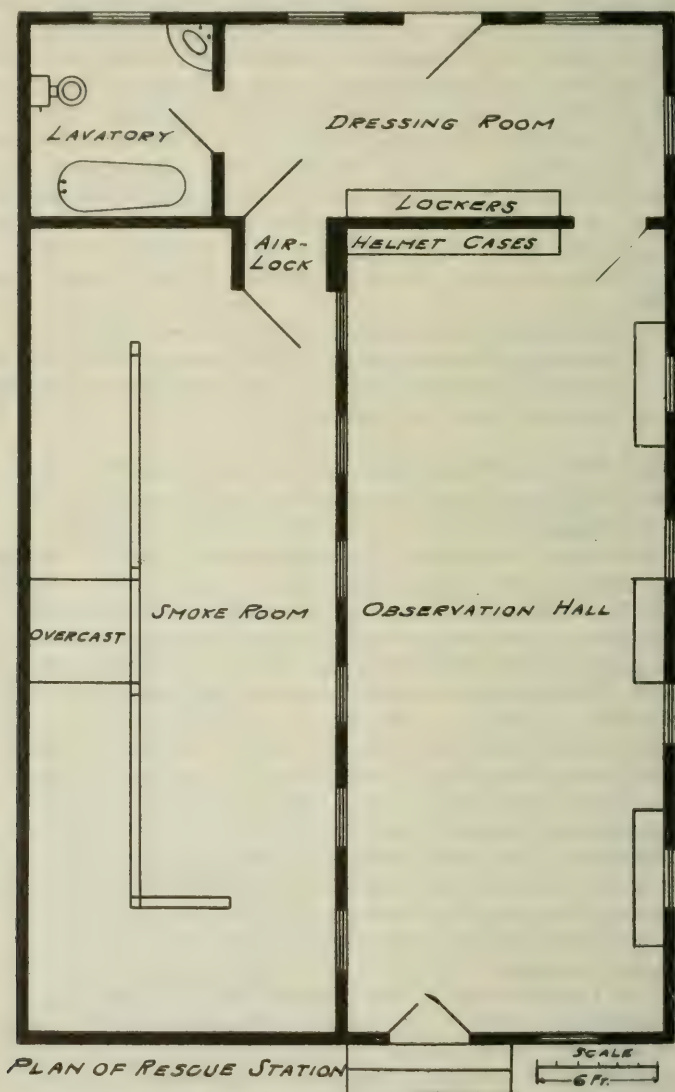
In general, by a joint rescue station is meant one specially designed and equipped for a particular group of mines; located centrally to each of such mines by natural or special transportation facilities, and financed either on a "per ton" or a "share and share alike" basis by each mine benefited. At such a station, at stated intervals, a squad of men from each mine could report for training in rescue methods under the direction of an experienced instructor, assisted if possible by a physician. From such station the rescue paraphernalia could be furnished in the event of a calamity befalling any mine of the group without delay. There are four divisions of the subject which may be amplified:

- I. Design and equipment of a joint rescue station.
- II. Character of the training to be given at the station.
- III. General advantages that may be derived from the stations.
- IV. Plan for rescue stations.

#### I. THE DESIGN AND EQUIPMENT OF A JOINT RESCUE STATION.

Breathing appliances were invented abroad and their use established long before we in this country recognized their value. But if we study the design and equipment of these foreign stations, we might be discouraged in an endeavor to copy them. Conditions abroad and in this country are entirely different; and valuable as is a study of foreign methods, we could not afford the luxury of such structures as the Howe Bridge Station in England. There are, however, certain requirements that must be followed in design. The station building should contain a gas-tight room, forty feet long by twenty feet wide and ten feet high. The interior of this room should be fitted to resemble a mine and to afford opportunity for the practicing miner to do work similar to that required in the event of an actual disaster. In a number of stations already built in this country, it has been the practice to divide this room longitudinally and to construct an overcast on one side, the aim being to present a passageway about the room, the travel over which would represent the journey of a rescue party through the entries of a mine. This room should be furnished with mine props and a frame consisting of four pieces of 6 by 8 timbers joined together in the shape of a square and tied with two iron rods, in which props may be set and capped with wedges; also brattice cloth, stretchers, and a canvas dummy filled with sand and sawdust so as to weigh about one hundred and sixty-five pounds. In order that men may gain confidence in working in the presence of gas, sulphur candles may be burned in this room to form a choke-damp; charcoal may be fired in open salamanders yielding blackdamp;

hydrogen disulphide may be generated producing stink-damp, or ordinary dense smoke may be obtained by burning dampened excelsior.



PLAN OF STATION FOR MINE RESCUE WORK.

It is not sufficient training in the use of the safety appliances, and protection to the miners, to have some of the miners put on helmets and walk about or climb up into the tippie. There have been

instances where men who have had such preliminary practice, when called upon to work in the mine in the presence of gas have lost their confidence because of their knowledge that it was a dangerous situation. When this happens, the mental condition of the men is such that they require more oxygen than the machine will give, with the result that they may collapse and have to be carried out. It is to give this experience and confidence in the apparatus that the smoke room is provided.

The experience of Mr. Roberts in the state of Washington with some of the mine operators shows this condition. Some of them took the position that it was not necessary to send the men to the station for training, as they could get it at the mine. Notwithstanding this, one of the operators was called upon to furnish a squad of men to be drilled in the use of the helmets, etc., in the smoke room. The first trial was but a short one, as the men were nervous and they could not stand the strain; they came out of the smoke room perspiring profusely. But that same squad, some three days later, did a good deal of hard work—building brick walls, carrying around the dummy, and such other work as might be necessary in case of an accident in a mine—and came out after two hours work far less fatigued than the first time. This shows that the men's mental attitude toward rescue-work and wearing the protective devices in the presence of smoke and gas has to be trained. Such experiences show that the little rescue stations, which do not look so very much like a mine, are very valuable.

Adjoining the smoke room and separated from it by a glass partition should be an observation room where visitors may sit and view the work of the miners. Here, too, the instructor may observe and record the performance of each member of the rescue squad. In this room there should be wall cases in which the rescue apparatus may be hung and protected from dust; there should be work benches to facilitate the cleaning of instruments and the charging of electric safety lamps; and a place to store the cases in which the apparatus is shipped.

Back of the smoke room there should be a lavatory containing toilet, shower-baths and lockers for the accommodation of the miners coming to the station for practice.

The equipment of the station should include oxygen helmets, or other suitable breathing appliance furnishing a dependable supply of pure air, with the aid of which men may safely enter any kind of the foulest and most poisonous atmosphere in order to perform rescue work.

Apparatus and supplies for recharging these machines.

Portable electric safety lamps with a convenient device for recharging.

A supply of some standard make of oil-burning safety lamps.

One or more resuscitating cases for use in reviving men overcome by the afterdamps of mine fires or explosions.

Special cases or trunks, of convenient size for handling, in which the above apparatus may be quickly packed and safely transported to the scene of an accident.

## II. THE CHARACTER OF THE TRAINING GIVEN AT THE STATION.

The character of the training given should include a general study of the conditions that obtain during and after a mine fire or explosion, with special detailed reference to concrete cases. With these actual occurrences in mind, plans should be discussed for successfully solving these problems according to modern rescue practice. The principles on which the machines used at the station are constructed and operate should be explained; and a thorough first-hand knowledge of the manipulation of the various apparatus should be acquired by the practicing miner. The actual training of the mind and body to do work similar to that required in the actual recovery of a mine and in the presence of deadly gases should be given by means of drills in the smoke room. In this way, men become acquainted with the possibilities and limitations of the machines, gain knowledge as to their own prowess as rescuers, and learn to work in squads under the leadership of one of their comrades. For mental and physical ability shown in the work, a certificate of competency should be awarded. This would tend both to keep up interest in the work of the station, and to be of especial value as a reference card when a disaster occurs.

## III. GENERAL ADVANTAGES THAT MAY BE DERIVED FROM THESE STATIONS.

The advantages that would obtain from such stations are in a large measure obvious. It often happens in an explosion that the ventilation machinery is thrown out of commission or totally destroyed. Also it is often necessary after a gas explosion to stop the fan to prevent a series of subsequent blasts and to control a mine fire by cutting off all ventilation. Previous rescue methods have afforded only a choice between two evils; either close the mine with concrete stoppings and leave it sealed indefinitely, or start the fan, send in the men and trust to luck, with the result of the loss of many lives and much property.

With the introduction of modern practice, however, rescue work assumes a decidedly different aspect. With the aid of the breathing appliances, trained men may enter the mine at once with comparative safety and begin the task of recovery, without aid of air supply from the fan. As the work progresses, each step may be taken with a complete knowledge of the situation gained from the careful reconnaissance of the helmet men.

Not least among the advantages that would accrue from the employment of rescue stations, is that in cases of emergency there would be available squads of men trained for the under-

taking, accustomed to working together and obedient to the commands of their leader.

A further advantage is that such rescue stations may become centers for the dissemination of knowledge among the men. In addition to the usual studies and lectures, local institutes could hold their meetings in the observation hall of the station; and talks and demonstrations on First Aid work could be given by the town or company physician with a view to forming First Aid Corps similar to those that are meeting with such success in the Anthracite Fields of Pennsylvania.

#### IV. A WORKING PLAN FOR RESCUE STATIONS IN ILLINOIS.

It is clearly out of the question, in view of the destructive competition that at present exists in the coal trade of this locality, to legislate against the very life of the industry by requiring each operator to establish a rescue station or make other improvements not immediately necessary. And yet, considering all that has been and is being done by foreign and domestic stations, and remembering the advantages that would accrue from the establishment of these stations along the lines of discipline, education, etc., we are compelled to recognize their value.

The Legislature of Illinois appropriates annually \$193,000 for investigation in agriculture. The mining and metallurgical industry of this state represents an output valued at approximately \$150,000,000, and for the aid of these industries the state appropriates only about \$25,000. In establishing and maintaining charities and schools, the state annually spends enormous sums; and while rescue stations are primarily devoted to training tending to life saving, they are or may be considered as educational centers. Moreover, the state has appropriated \$2,500 for the relief of the sufferers of the Cherry disaster, and the legislature is now considering bills calling for an additional benefit appropriation of \$50,000 to \$150,000. In view of these facts, it seems reasonable to ask the legislature for a grant of funds sufficient to carry on work which has for its object the saving of life and property, the training of its citizens to be effective agents of a vast enterprise and the reduction of a constantly increasing number of deaths, a special appropriation of \$30,000 and in addition an annual appropriation of \$30,000, to be expended according to the following plan of operation:

The coal field of Illinois would be arranged into three divisions, and in a centrally located city or town in each of these districts a central rescue station would be established. For example, LaSalle, Springfield, and Carbondale. Each of these three cities is a railroad center, enjoying exceptional railroad facilities. A station could be built for \$5,000, and equipped with a complete line of apparatus for a like sum, itemized as follows:

- 12 oxygen helmets, or other suitable breathing appliances.
- 12 portable electric safety lamps.
- 12 oil-burning safety lamps.

- 6 oxygen tanks or reservoirs.
- 1 oxygen pump.
- 2 oxygen reviving outfits.
- 200 potash cartridges.
- 1 chemical cabinet for gas analysis.
- 15 cases or trunks for transporting the above apparatus.
- Furniture, including chairs, tables, wall cases, etc., tools, supplies, etc.

In that list I wish to call attention to one thing, and that is the chemical cabinet for gas analysis. This is about the size of a dress-suit case, on end, but a little lighter. It is portable and can be taken right into the mine and a sample of the mine air can be put through the apparatus and give information as to the character of the gas to be encountered. On one occasion almost a panic was created at a disastrous mine fire by the statement that "White damp is being generated in enormous quantities." But some of the miners, having prepared themselves, had taken samples of gas and put them through the machine and demonstrated that the alarm at the presence of CO was groundless. The apparatus is inexpensive and can be used to advantage, especially in the southern fields where large gas pockets are encountered.

Thus, the three stations could be completely installed for the special appropriation of \$30,000.

In charge of each of these three central rescue stations there should be appointed a man whose experience in coal mining has been large and varied—someone who can maintain the interest of the miners who visit the station, care for the apparatus, and keep the records. Over the entire rescue work, with power to purchase supplies, direct the course of training, and assume the entire charge in case of a mine disaster, there should be a man who is a mining engineer by profession, one who has had experience in all phases of coal mining, including mine rescue work, and one upon whom may be thrown with confidence the welfare of the whole proposition. It is proposed that such officer co-operate with the inspector in whose district a disaster may occur. It is also suggested that he report to a board of five persons to be appointed by the Governor, to consist of one inspector, one operator, one miner, the head of the Department of Mining Engineering at the University of Illinois, and one member of the Federal Inspection Force.\*

Each operator of the state should be asked to send a small

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\*This paper was written in December, 1909. On the 14th of that month, Mr. F. W. DeWolf, Director of the State Geological Survey, and the author, were in Springfield, discussing the ways and means to increase interest in mine rescue work. The idea occurred of dividing the state into three sections and asking the State Legislature for an appropriation for creating and maintaining three rescue stations. We worked out the details there and then, came to Chicago to lay the matter before the Mine Commission and certain of the coal operators, with the result that a bill was introduced in the Senate which became a law. This bill increased the appropriation from \$60,000 to \$75,000 and changed the governing board of five members to a commission of seven. So, part of the original paper is now a back number even before it is presented tonight.

number, say 4%, of his employees to the nearest of the central rescue stations at least twice a year for training in rescue work. These men should spend at least three days at the station on each visit. In return for this action of the operator in bearing such expense for the safety of the lives of his miners, the men so trained should agree, in cases of emergency, to assist in the work of mine rescue, with the understanding that they are to receive only the "inside wage scale" for time devoted.

I was in a mine one time where some bodies were to be removed. The superintendent of the company felt that the men who had been used to working in that mine ought to be given the opportunity of removing those bodies. The men immediately held a meeting and decided that they would do it providing the superintendent would guarantee \$1.25 an hour, which is quite a little above the inside wage scale. The superintendent then became indignant and said that he would rather get store clerks at \$10.00 an hour than give those fellows anything if that was the way they felt about helping to relieve the situation. The time to arrange the details, or as many as possible of the details, is before the calamity occurs, and I really think if the operator goes to the expense of training his men and giving them the opportunity of coming to these stations and becoming proficient, that when anything occurs they should be willing to work for the inside wage scale. Then, if the operator feels like it, he can add to that at any time. But there ought not to be any haggling about price at the time there is something to be done.

These three central stations could be made of great value to both miners and operators. But one further step is necessary to complete the plan and insure its entire success, because, even with the three stations thus located, there would be an appreciable lapse of time before the apparatus could be delivered to a mine in case of trouble. So to overcome this delay, the suggestion is made that all operators combine in what may be called local or private stations, consisting merely of five helmets and five electric safety lamps, charged and packed in cases, ready for transportation, in some town or a mine where there is always someone present who can deliver the helmets as needed. This local station might be in a fire department house of the town. These local stations would serve all mines within a radius of fifteen miles. As the station equipment would consist of the five helmets and lamps, without any of the costly apparatus for recharging them, the expense, when divided among all mines within the 15-mile-radius circle, would be very small. It would be the duty of the central rescue station people to inspect and charge these helmets periodically and see to it that they are in working condition for an emergency. This might be accomplished by having the local helmets brought to the central station by the miners when they visit it for training. The object of the local stations is that the men at the mine may, in case

of fire or explosion, have means at hand for preliminary work, or immediate rescue that may be necessary during the period while the men and equipment of the nearest central rescue station are journeying to the mine.

In concluding this paper I can assure you that I am urging the adoption of certain engineering principles that have been of inestimable advantage wherever used legitimately, and which have as their object the conservation of life and property.

#### DISCUSSION.

*Mr. A. Bement, M. W. S. E. (Chairman):* Coal is something that we all have to do with and we all know something about it. Coal and coal production is a broad and deep subject; there is much to learn about it and we are learning about it all the time. This Society has in various ways contributed to a knowledge of coal and the coal business, and a considerable number of our members are interested in the subject in one way or another. Our state has taken an active position in many ways; for instance, a geological survey was recently established which will necessarily give much attention to coal, because it is our most important mineral resource. In the past we have been comparatively free from accidents in coal mines, principally because our coal seams are less dangerous than in some other states; but conditions are changing, and in the last few years we have begun to make a record in accidents; we have had some three or four serious ones and a great many that were not so serious, but all were accompanied by a distressing loss of life and property.

The Technologic Branch of the United States Geological Survey has in recent years—the last two years particularly—been giving special attention to the matter of coal-mine accidents and their prevention, and it is doing some very good work in that line—better work, I think, than it did previously in the testing of coal. It has made a thorough study of the matter, has done much experimental work, and has a very capable corps of engineers engaged in its service. One of our members, who is, I may say, connected with both our State and the United States Geological Surveys, has given special attention to the matter of rescue work and has made a great effort to secure the establishment of a working system of rescue for coal mines. He has endeavored to get the mine operators interested in the proposition, not only from the standpoint of the conservation of life, but as an economic scheme in the handling of their properties. When a coal mine catches fire, it may be but a very small fire as we look at fires up on the surface, but it is quite a different thing in a coal mine. A fire cannot be approached from all directions, and the products of combustion necessarily travel in the roadways or the passages which are quite confined and in which it is difficult for men to travel to reach the fire. Thus a simple and small fire makes a great deal of trouble; it may readily get beyond

control, and may result not only in destruction of property but in loss of life.

The paper presented tonight by Mr. Williams introduces a matter which should lead to useful and valuable discussion. There are also some side issues bearing upon the problem. While this paper advocates a scheme requiring some legislative action by the state, it was prepared before the legislation was enacted. So we already have the answer to the author's appeal, as a bill has been passed providing substantially for the scheme which he suggests.

In addition we have had some other legislation; a telephone system in the mines is now required, and also a system of danger signals. The telephone seems to be accepted by the operators as quite a convenient and useful device. There is some difference of opinion as to the danger signals, and it is hoped that there may be some discussion of these problems.

It has been, I dare say, generally recognized that the device known as the helmet is a very useful thing, and certainly, if by putting it on, a man can go into an atmosphere that will not support life, it is a great convenience, and a great help. At first the idea is likely to present itself to us as simply strapping on the helmet and attaching the parts of the device; in fact, it has been employed in some cases, in many cases, probably in almost all cases, in that manner, assuming that all that it is necessary to do is to put it on and start to work. But it has developed that there are many other features and difficulties; one is that the man may be nervous; he may be in or may get into a physical condition requiring a larger amount of air—a quantity of oxygen that the machine does not supply—and he may exert himself physically beyond the capacity of the machine to supply the oxygen required, which introduces difficulty. In that connection I think we would be interested in having Mr. Williams tell us to what extent the helmet device is capable of supplying oxygen according to the requirements of the wearer. In other words, is the supply variable to any extent? My understanding is that it is constant, and that it is considered that the man should accustom himself to the amount of oxygen available rather than expect the machine to supply his needs which may be variable. I think it would be well if this point could be made clear.

In the case of an explosion in a mine, the mine often becomes inaccessible through the disabling of the cage. Then it may be necessary to let a man into the mine, with no appliances at hand for that purpose, and the problem is to hunt around and find a rope and a bucket to put him in, and lower him into the mine. This is very unsatisfactory and it does not make work any easier for the man. If he is let into a mine in a bucket that he cannot conveniently stand in, which, in striking an obstruction in the air-shaft, arrests the motion of the bucket until the rope pays out, and which then gets loose and drops with him until the slack is taken out, it is not a very pleasant experience, especially when he is closed up in the helmet and loaded with forty pounds, in addition to a fifteen-pound

storage-battery light. It appears to me, and it has been stated to the Society before, that a necessary accompaniment of a helmet equipment is a device for letting men into a mine—something in the way of an emergency cage in which a man can stand safely. The provision of a rope with which to let him down, and facilities for running that rope over a sheave at the top, are very important matters. At Cherry, at Ziegler, and at other places great difficulty was encountered in letting the men into the mine and work was greatly interfered with owing to lack of such equipment. If a man is to explore a mine, it is always desirable that he be familiar with it. It is difficult for a stranger to go into a mine and find his way about in the dim light and do effective work. It is not only at all times desirable that men who are familiar with a mine should go in and do the work, but it is in a very large degree necessary. This emphasizes one of Mr. Williams' arguments that it is necessary to make these local provisions for properly utilizing the service that may be had from the helmets.

*Mr. Frank W. Dell'Wolf*, M. W. S. E. (Illinois State Geological Survey): It has been a great pleasure to be associated with Mr. Williams during this last year in the work which he has been doing. It has been a great pleasure, also, to be in this state during the constructive period through which we are passing and have already passed, as affecting the coal mining industry.

Some of those present may not realize the radical steps which have been taken during the last four or five years in Illinois mining. Looking back to the establishment of the Geological Survey in 1905 as perhaps the first of the new steps, although not necessarily the greatest, there have been a number of advances made. The Mining Investigation Commission has done and will still do much to improve conditions. Our new school of Mining Engineering, established two years ago at Urbana, and organized under Mr. H. H. Stoek, certainly fills a great need. More recently the provision by law for a mine rescue commission—which has not yet been named by the way—marks the latest advance. Another helpful measure, looking forward to the establishment of mining institutes, was presented to the last legislature also, and was acted on favorably by that body. Unfortunately, the Attorney-General decided that such legislation did not properly fall within the scope of work of the special session, and it became necessary to veto the bill. This is one of the measures for which we look to the meeting of the next general assembly. It should provide means for educating the miners in safe, efficient, and economical methods of mining.

In all this progressive work that I have mentioned, federal co-operation has been prominent and always advantageous. The State Geological Survey co-operates with a number of federal agencies, among them the Technologic Branch, to which Mr. Williams belongs. He has been with us entirely at the expense of the federal bureau; so we give them the chief credit for what has been so well accomplished during this last year. More investigations by the federal au-

thorities are needed. Those who have been looking forward to the establishment of a government Bureau of Mines are greatly pleased to know that a bill for this purpose has just passed the Senate and will probably be enacted into a law. Under the new bureau, if it is properly conducted by a man who is broadly familiar with technical problems and with the mining conditions of this whole country, we can look for still greater and perhaps more radical advances in safe and efficient mining.

Mr. Williams has been rather modest this evening in disclaiming credit for this movement which resulted in the establishment of state rescue stations. The idea is his from start to finish. It has been necessary, of course, to proceed along the lines of least resistance; to present it to the proper officials; to get the support of the mining commission; and then to go to work at Springfield and put the thing through. The idea was worked out by Mr. Williams in response to a suggestion from Mr. Bement some time ago that a symposium on certain aspects of the coal business in this state should be prepared. The effectiveness of the paper is indicated by the legislation which has already been obtained. Many of us know of Mr. Williams' personal achievements during the past year in this work. He was in charge of the helmets during the early days at Cherry, and was one of the two men who went down in the bucket for the first examination. At that affair, and also at many fires in this state which were dangerous and called for a high degree of confidence as well as mining engineering ability, Mr. Williams has been at the head. His whole work under the general direction of Mr. Rice, a fellow member of this Society, and of Dr. Holmes, Chief of the Technologic Branch, has been as fine a demonstration as one could wish, that a timely idea presented in a logical and aggressive way will bring forth the desired fruits.

*Mr. Bement:* Mr. DeWolf has mentioned the probable establishment of a Department of Mines as one of the bureaus of the government. I dare say that we are entitled to hope that we may derive considerable benefit from such a bureau. To me it has been a great regret that the Technologic Branch of the Geological Survey, while claiming conservation of natural resources as one of its great objects, has never taken up the consideration, or exploited the idea, of better methods of mining, or the uniform establishment of better conditions over the country. Those familiar with the commercial side of coal production and the sale of coal know that competition between states and between localities is a very disturbing and uncertain factor. Thus when one state has a serious accident, as we had here recently in Illinois at Cherry, the people demand enactment of laws tending to make mines more safe. Those things lead to the expenditure of considerable money. It puts an increased cost on coal production, but our neighboring state or other competitive states are not required to make such improvements. So we burden our industry, while the competitive state does not. There is no

doubt, of course, that certain important safeguards should be provided, and that we should have certain restrictions; the coal operator desires them; the public in general would be benefited. But it is manifestly unfair when we have an expensive plant required for Illinois, when some other state may use a cheap one.

Another phase is that of conservation. In the older established countries very different methods in the recovery of coal prevail. The recovery is very large and the waste is small. With us it is probable that 50 per cent is recovered and the rest is left in the ground and wasted. It is wasted because it would cost more to mine it than it would to mine into additional new territory. It is not necessarily left to be lost because the operator does not care; it is left because he cannot afford to remove it. If the conditions were such that it was necessary for all of it to be removed, he would be perfectly willing and glad to do so. It would prolong the life of his territory. It would give him the recovery of all the coal that he has bought. This is a matter which I think the Technologic Branch has failed to consider as it should, and it is something which I hope this new mining bureau will take up. When we talk about it we are told, "O, that is a matter of state rights and the government cannot interfere with it." But we see a number of things that the government does step in and interfere with—things that some people call state rights. So we must have consideration of matters of this kind, and have them discussed and the necessity made plain, before we can secure the remedy. I hope that this new mining bureau will take up that phase of the mining business.

*Mr. John A. Garcia* (Brazil Block Coal Co.): I feel sure that most coal men—especially the coal men in active management of dangerous properties—will agree with me when I say we will welcome anything that can be done to aid us in solving our explosion and mine fire troubles, and help us in the rescue work.

I have had some personal experience with the helmet, and have seen Mr. Williams, Mr. Webb, Mr. Rice, and several others work with it, and I want to give them all the encouragement I can. I have personally sent men to the Urbana station for drilling in the work, and have been there myself. I believe in the helmet and know good work can be done with it. I am sure that, properly handled, it will help a great deal; but without a trained corps of men I believe that the helmet is worse than useless, because it is a very difficult proposition for a man to enter a coal mine after an explosion has occurred. He has to go down several hundred feet in a shaft, and, being in the gas, realizes that if the least little thing goes wrong with the helmet it generally means death, so there is little hope for him.

When I walked around through Mr. Williams' smokehouse I carried a 135-pound dummy, and I must confess that it felt more like a ton than it did 135 pounds. This brings out a feature of the helmet work that I think everybody connected with mines, at least,

should understand, and that is that one cannot do hard work with it; I believe that men should not go into mines with helmets on without understanding that fact. In going down in a bucket, sometimes one can get off and sometimes he cannot. A man can go into the mine and hang brattices and possibly a door; carry props around slowly and with great care, and if a man is found he can be dragged out, or two, maybe three helmeted men can carry him out. Unless the men are trained in that work by personal observation and experience, they are apt to rush right in, and if they find a man they will grab him and hurry out. Sometimes they will get out and sometimes they will not. They cannot breathe freely. I think I am right in saying that the helmet feeds the oxygen at a fixed rate and one has to work in accordance with that oxygen supply. A helmeted man cannot carry a man; he can only drag him; he cannot go fifty feet without breathing hard; he cannot put up a prop or cross-bar without breathing hard, and every little while he will have to sit down and get his breath. I am positive that the ordinary man around a mine cannot wear the helmet without some experience, and I would not send a man into any of our mines unless he was trained in the work.

Now, Mr. Williams is a very practical man and his idea of having local stations and trained men is certainly born from experience. He realizes that he cannot go to a mine and get men around there to go down the shafts and carry out dead men or live men or put out a fire, unless the men are trained. If we could always have men like Messrs. Williams, Webb, and Rice, as we had at our West Franklin disaster, it would be all right; but we cannot always get such men. We sent a man into the fan conduit on the top when our No. 18 mine exploded at West Franklin. He had had no experience with the helmet, and at the end of five minutes we had to drag him out, and I am sure if he had had to depend on himself to get out he would have been there yet. I understand there was considerable difficulty at Joe Leiter's mine on account of the men not being familiar with the apparatus, one, at least, having lost his life.

Aside from that, I have always found that the one great trouble in rescue work was getting into the mine. Under the present system of mining in Illinois two shafts are used—one for hoisting and one for the air. The air-shaft is generally an escape-shaft, and has a ladder or a cage in it; one is dependent on the other; the air goes down one and comes up the other. If an explosion occurs, both shafts suffer. I have visited a number of mines after an explosion, and have always found both shafts in bad shape. The new mining law compels all new shafts to be concreted, but I do not believe that solves the problem, because in the event of an explosion the shafts, being interdependent, will be wrecked and one cannot get in. If there could be a third compartment on the hoisting shaft, through which to transmit air to the various workings of the mine, the air to be returned to the surface through the hoisting shaft, it would

furnish as good ventilation as is obtained today. In addition, another shaft, equipped with ladders, and possibly a cage, could be sunk as a real escape-shaft, and a very narrow entrance into the workings of the mine, equipped with a heavy iron door, would probably protect the shaft from the effect of explosions. The cost of that construction would not be much more than the present, and it certainly would permit of entrance into the mine after an explosion.

Last month I happened to be at a mine needing repairs, and sent a number of men into it. While I was waiting for the cage there was an explosion, and the gases and smoke were coming out of the hoisting shaft. I was the only one around there and must confess that I didn't know what to do. I finally got a man to go down the air-shaft with me; we could not go down on the cages. After getting half way down I was so weak from climbing down that I could not go back, so I had to go on down. We went 1,500 to 2,000 feet into the workings, following the air. There we found the men and they could scarcely walk. I led them down to the air-shaft and told them we could not get to the cage because there was so much smoke in the cage room. Those men desired greatly to get out; they were badly scared; but when I told them that they must climb the ladders they said they would stay there and die first; they refused to climb those 500 feet of ladders, and would not even start. So we finally made a break for the cage and got out that way. Now, imagine a man with a helmet walking down 500 feet of ladders, walking 2,000 or 3,000 feet into a mine, and carrying a man out. I do not believe it is possible, and I am convinced that we not only need the helmets but a different arrangement of shafts. With the above arrangement for shafts, the helmets, a trained crew, and the concrete shafts, I think we have the problem solved, possibly with the addition of permissible explosives. With the elimination of the black powder in a coal mine, I think that 75 per cent of the danger from explosions will be eliminated, or practically done away with.

*Mr. Bement:* The gentleman who sells the helmet which I think has been used almost exclusively in this country, in this part of the country at least, told me that the largest customer he had was not one in the coal mining business, but in quite a different industry—in the steel business; the Illinois Steel Company he said had bought more helmets from him than any other purchaser; that they used a very large number for the men who work about the blast furnaces, in the gas washers, in connection with the gas plant, the gas engines, and the furnaces; that they find it very useful and a great help. This illustrates a simple application. The element of danger in their use that we have in coal mines is largely absent.

*Mr. F. D. Chadwick, M. W. S. E. (Spring Valley Coal Co.):* I came here this evening to pick up some pointers that would help us in our rescue station at Spring Valley, and not with the thought or idea of saying anything. I am therefore unprepared to discuss Mr. Williams' paper, but will try and describe as briefly as possible the

rescue station that the Spring Valley Coal Co. has established at Spring Valley, Illinois.

A few months ago we started in with three helmets, which have since been increased to five, and the necessary boxes and appliances pertaining to the same, one pump for filling the oxygen bottles, one resuscitation apparatus, one water-gauge, and a stretcher-board. This stretcher-board has attached to it an oxygen bottle and a mouth-breathing piece which fastens over the mouth and nose of the overcome miner when placed on the board, and he can then be brought through gases safely.

As none of us had had any previous experience with a rescue station, we had to begin in a more or less crude manner. In order to familiarize the men with the apparatus and get the best results, we thought they should first understand the mechanical workings of the machines before putting them into actual operation, so that they would be convinced in their own minds regarding the degree of safety with which these machines could be used. With this idea in view, we formed a squad of men at each mine, consisting of three men from the top and five men from the bottom, selecting men whose intelligence and physical condition made them the most adaptable to this class of work.

We have the Westphalia apparatus, which is made in Germany, and I believe that it is the only outfit of its kind in this country. It is somewhat different from the type of instrument used by Mr. Williams, in that it has no check valves, but has a constant circulation under a 5-in. water-gauge, which is regulated by an injector which feeds the fresh oxygen into the air that has been purified by passing through the regenerator.

After we considered the men sufficiently familiar with the apparatus to warrant their wearing the helmets, we had them put them on and two of the men carry the stretcher, with a man weighing about 200 pounds, back and forth in the office, which is about 75 ft. long, a total distance of about 700 ft., with strict instructions not to open the helmets under any consideration, as we wanted to demonstrate to them that no matter how hard they breathed or even if they felt at times that they were not getting any oxygen, that the machine was working all the time and generating oxygen, and that by resting for a few minutes they would find that they had plenty of air to breathe. In one of our drills two of the men opened the helmets, claiming that they could not breathe, so we had the men take them off, and later put them on again, and go through the same performance, explaining to them that then was the time to sit down and wait for the machine to catch up in its supply of oxygen to the amount they were consuming. This is about as far as we got with our drill when the suspension of mining operations came. As soon as the suspension is over we are going to take our men to our No. 4 mine, at Seatonville, where we have an entry about one-half a mile long, that is filled with black damp. We will give the men safety lamps and electric lamps, and have them go into this entry, and as soon

as the safety lamps go out they will know that they have to rely entirely upon the apparatus. We will then have them build stoppings and put up brattice, clean falls, etc., in other words, go through, as nearly as possible, the actual work as it would be required should we ever meet with an accident requiring the use of the helmets.

One of the helmets is to be connected with a telephone, so that the party under ground will be in constant communication with the surface, thus giving them a feeling of a greater degree of safety. This idea, they tell us, has been worked out successfully in Germany.

*Mr. Bement:* We would be interested in having Mr. Chadwick give his opinion of the new mining law as applied to a long-wall mine.

*Mr. Chadwick:* I have not formed an opinion with the exception that the new law is going to be a great expense, and that the gong system in a long-wall mine is going to be very hard to maintain. We run all of our entries at 45°, the main entries being about 1200 ft. apart along the face. Off of these main entries we branch entries to the right and left every 225 ft., with about four rooms turned off of them, off of each entry. The new law requires us to put in one gong on each main entry and one can readily see that our panel system is just far enough outside so that we will have to put in intermediate gongs between the main entries. We are also required to keep these gongs within 250 ft. of the face.

We take out approximately 3½ ft. of coal and 6 in. of mining dirt, replacing this with a pack wall, which makes our settlement in the mine 2 ft. As the roof is gradually sinking this distance of 2 ft., it will be readily seen that it is next to impossible to maintain timbers while this settlement is going on, so that we will be constantly replacing timbers to hold our gong wires. This settlement is constantly taking place as far back as 1000 ft. from the face.

Mr. Garcia spoke about having three compartments in the hoisting shaft; one being for air, and having the escape-shaft divided into two compartments—one compartment for stairs and the other with a cage in it to bring the men out in case of trouble. We have this condition in two of our mines. One of these mines has brick walls on the bottom and an I-beam roof for a distance of 300 ft. from the shaft, so that it will be seen that we are in line with his suggestion as to the proper construction of the shafts at a mine.

*Mr. Williams:* How much does the Westphalia machine weigh?

*Mr. Chadwick:* Just about the same as the Draeger machine.

*Mr. Williams:* The principle is about the same. Both of them are regenerating machines having oxygen under storage.

*Mr. Chadwick:* The Westphalia machine is a little different, not having the check valves, but a constant circulation of oxygen.

*Mr. Williams:* With your machine the potash is in one can while ours is in two.

*Mr. Chadwick:* Yes, we have the refillable type of regen-

erator, our chemical coming in sealed tin cans which is placed in the regenerators.

*Mr. Williams:* There is a machine going with the Draeger device also, whereby replenishment can be made without spending a good deal of money buying new cartridges.

*Mr. Bement:* The new law requires a telephone in mines, and it seems that the telephone is quite a popular thing among the operators. It is invaluable to those on the surface, and it is rather surprising that the advantage of the telephone has not been recognized for other places than between houses and business establishments in cities and towns. We have with us Mr. E. C. Lewis, of the Stromberg-Carlson Telephone Manufacturing Co. His company has installed a good many telephones, I believe, and I am sure that he can tell us something of the use of them in mines, the difficulties that are experienced with the gong signal and the objections to it, and the purpose for which it is required.

*Mr. E. C. Lewis:* Mr. Williams spoke of rescue stations and sub-stations. He neglected, however, to state how we were going to report this disaster to the sub-station.

*Mr. Williams:* The idea, as brought out in the bill, is that the main central station shall be in operation or have a man there at all times. The mines—almost all that I have ever been in—are connected with the outside world by telephone, and the smaller stations in the 15-mile-radius circle would be in telephonic communication with each of the mines in that group, and also a through line to the main central station. It is your equipment, or something like it, that will have to be used. That is the only way I know of getting word.

*Mr. Lewis:* That is the point I wanted to bring out—the *telephone*. I heartily concur with this rescue work, you understand, but when there is trouble it must be reported to the central station or sub-station. How? By the telephone. There are mines in the state, I understand, with entries running back for a mile. If there is trouble at the face, without the use of the telephone, some one must go to the bottom of the shaft, where no doubt there are speaking tubes, and then report to the top. From ten to fifteen minutes' time will be required for the trip. In Colorado there is a mine that has been in operation over forty years, it is now back some three-and-a-half miles, so one can readily see the time that would be required to report trouble without the telephone. With the telephone the trouble can be reported immediately and a physician or an ambulance can be on the ground in case some one is injured. In fact, in one case of accident at Divernon, a doctor was at the top of the shaft before the injured man was out of the mine. In that way the telephone has become a commercial proposition. The company with which I am connected has been making mine telephone equipment for ten years. The business, I will say, has been largely foreign, and up to the time that this present law was passed there were not to exceed two dozen mines in Illinois equipped with telephone service,

and in the majority of cases there was only one telephone at the bottom of the shaft and one at the top. Now there are a number of other mines that have taken up the telephone. At Divernon some two weeks ago, the Governor, Mr. David Ross, the State Mining Inspectors, and a number of mining men were there for the purpose of investigating the gongs and mining systems. While there the Governor talked to his office in Springfield. So it will be seen that the mine telephone may be placed in direct communication with service outside. In that way one may bring the rescue work to the mine much more quickly than otherwise. In other places the telephone has been brought to the attention of the operator by the process of evolution. In Illinois it is different. Here it was a revolution, and by some of the operators it is resented, especially the gong feature, but most of them take kindly to the telephone. I regret to note, however, that there are a few who seem disposed to get out just as cheaply as possible.

The matter of installing instruments is left largely to the discretion of the operator. I think those present are familiar with the provisions of the law, which provides that there must be one telephone within 100 ft. of the top of the shaft. This may be located wherever it is desired, but in the majority of cases it is in the engine room, I think, and sometimes with an extension over to the office. There must be a telephone at the bottom of the shaft. There must be one on each side of the mine if it extends back over 1000 ft. In addition thereto, there must be one telephone for each 100 men, or major fraction thereof in excess of 100, so that if 400 men are being employed, six telephones would be required at the bottom of the workings, which may be placed at the option of the operator. In the majority of cases they are placed at the partings or lyes, where men are usually placed.

When it comes to the question of gongs I dislike to say anything about them. It is a hard problem with everybody. The law calls for a system of gongs. Mr. Chadwick says the long-wall man is going to suffer. I think the room and pillar man is going to suffer also. I have in mind a case where only eight telephones were installed in the workings, while thirty-six gongs with 36,000 ft. of wire connected with the gongs were required. It is a serious proposition. The question of installing the gongs is open to some discussion. The law does not state that they must all be operative at one time. The gong sections may be in splits, so that different parts of the system may be signaled if desired, without disturbing the others.

The point has been raised that this gong system will kill more men than it will save. I believe that point is well taken; that if we put the gong system throughout the mine in operation, and start from 300 to 600 foreigners toward the rescue shaft or hoisting shaft, as the signal may designate, it will inaugurate a panic and really present a serious phase. The law is well meant, no doubt. In talking with

one of the commission who assisted in drafting the bill, he said, "We know that the gong is a bad feature, but we had to get out of it as best we could." It was a trade. A great many people insisted that all the shafts should be cemented from top to bottom. You know what that would do to some of our good brothers!

There is a discussion now among various operators relative to the merits of the direct or the alternating current. I do not want to take that up at the present time, because that is only a technical matter, but either one will pass inspection, as I understand the situation at the present time.

*Mr. Bement:* I dare say some of the speakers who have presented such valuable discussion will be willing to give us something more about the gong question. I think it is a very important matter and will add greatly to the value of the discussion of the paper.

*Mr. Garcia:* I would like to take this opportunity to go on record, as a member of the Western Society of Engineers, regarding the gong system. If it were not such a serious affair I would probably call it a joke. Mr. Lewis called attention to the fact that when those bells are rung there is likely to be a stampede, and I can readily understand that there will be a stampede in any of our mines where we employ from 300 to 500 men. I do not know how many of them are going to get to the shaft when the fire alarm goes off. They will come down the entry as fast as they can run, and when they get to the shaft some will go up the stairs, some will fight for the cage, and many will be injured. I really believe, after the first few false alarms and after the first few stampedes, they will repeal that law. I do not know of any instance, in the ten years that I have been connected with coal mining, when we would have had occasion to ring the gongs; possibly at Cherry; but even at Cherry it would not have done any good, because it was too late when they realized they should call the men out. When they did call them out and sent the drivers around to bring them to the shaft, the men could not get out. This fire-fighting proposition is going to cost us close to \$15,000, and all we will get out of it will be the telephone. I think the telephone is a good thing, and possibly the line of 1½ in. water pipe. I think we can use the latter, at least for watering the mules, if nothing else. The spray proposition is ridiculous. The sprays are utterly useless and cost money to install and maintain. There is not a man who has ever been around a mine fire but knows what a spray will not do to extinguish a fire. The maintenance of the bells in our mine will not be such a great item of expense except probably in the Danville field, where there is such a bad roof, falling upon and breaking the wires all the time, and breaking the insulation, thus causing corrosion and short-circuiting. Our working faces will advance about 600 ft. a month, in good working times, so that every two months we shall have to pick up the bells and wires, to set them forward. The great ex-

pense will be the breaking of the wires. I have been working all the week on this bell proposition. I have talked with engineers,—mechanical and civil,—practical operators. (Mr. Lewis here has given me a great deal of attention), and I have finally decided to use alternating current. I had my mind made up for direct current, but I began to think what would happen if a trapper boy got a little tired of holding down his hard job and would extend a wire from the trolley wire to a bell wire, resulting in a stampede. If we had a wreck, that trolley wire would be the first thing to hit the bell wire and it would ring the bells. If we put them within 250 ft. of the face of a gaseous mine, possibly we will blow the mine up. We cannot do that with the alternating bell, so I became a convert yesterday to the alternating system and we are going to put it in our seventeen mines. We are going to use one wire, No. 14 copper insulated, for bells, and the same wire for the telephone; and we are going to run all the wires down the air courses so that it will be a hard matter to get the trolley wire mixed up with it and do away probably with induction in the telephone system.

That is about as far as we have gone. We are going to have a ground-return, and if there are any electrical engineers here to-night, I would like to have them tell me what they think of a ground-return for fire gongs and telephones in a mine. Some of the mines are wet; in dry mines I do not know what we are going to get, but if the scheme does not succeed we will put in a third wire for return.

*Mr. Lewis:* I might say, for Mr. Garcia's information, that if he succeeds in getting a good ground, as we call it, he can ring more gongs and ring more telephones on a ground circuit than he can on a metallic circuit. That has been demonstrated a number of times in the country, where the farmers start out with a single wire and they tap on a telephone and connect it to ground and they go on miles out in the country—ten, fifteen or twenty miles—and they tap on not four or five but ten, twenty, as high as thirty-eight telephones I have known to be on one circuit, and they ring through. Some of them become dissatisfied with the ground circuit because there is so much inductive disturbance, so much cross-talk and so on, and so they make a change and then they find they cannot ring through. Theory might not back up that statement, but it is nevertheless a fact.

I want to urge this—if the Society wants to make a recommendation, that they urge operators to install good telephones, get out of the gong question as cheaply as possible, but install good telephones. Some of them are disposed to merely comply with the requirements of the law and put in any old telephone. One operator in the southern part of the state has bought some second-hand telephones and put them in a wooden box, because the law says that is a telephone. Perhaps that will satisfy the law, but we look on the telephone as a commercial proposition. We think the gong law will be repealed, but the telephone law will stick.

## CLOSURE.

*Mr. Williams:* The first question that was put tonight by Mr. Bement was a question of the flow of the oxygen through the helmet. I have a helmet here this evening. It is getting to be so well recognized, I am glad to say, that almost everybody present, I believe, has seen it, but I thought I would bring one along in case any one wanted to see it.

The flow of oxygen is a fixed quantity. There are seven or eight different machines; some of them have a valve that can be adjusted to suit the wearer. The Draeger people—whose machine we happen to be using—claim that a man that has that always has it turned to the extreme amount of oxygen, and he will use up his supply that much quicker and will have to return for a new charge that much earlier. He uses more than he really needs to. He also loses sight of the fact, in the excitement, that with the machine on, as Mr. Garcia says, as much work cannot be done as with the machine off, and this man with the oxygen turned on full blast, and under possibly the stimulus that it will give him for the time being, will go beyond his limit, get in the mine too deep, and be unable to return. Consequently, as a gentle reminder that there is a limit, the Draeger people have a fixed quantity which will allow a man to do an ordinary amount of work, but still he will have to keep watch of himself all the time he is working. That is one kind of a machine, and doubtless a Yankee will come out with a lighter machine. There is one machine now that can be bought for \$1.00 that can be used for twenty or thirty minutes and give just as good air as the Draeger machine. A man can take it in his pocket into the mine. It is just about the size our mothers used in putting up canned fruit—about a quart size, possibly a little smaller. He takes that into the mine with him and if anything happens he has a twenty-minute supply of oxygen with which to get out. That same principle could be carried still further. A man might have a helmet in which he screwed the powder charges needed with a little water there to liberate the oxygen; screw it in the same as he would screw in the carbide for an acetylene lamp; carry two or three boxes with him and increase the twenty-minute intervals as much as might be desired. I feel that it will not be very long before somebody will make a much lighter machine.

Naturally I would like to see whoever gets charge of the three rescue stations assisted by the operators in the state, because I think right there is something they might help. A year and a half ago there were just four helmets in the United States. Today, I venture to say there are a thousand, and probably during the next year—well, I know just one order that will go in for a hundred. If the foreign countries can make them fast enough, I imagine the helmet has come to stay; but I do not think we will have to go abroad for them. The price during the last six months has dropped on our

machine from \$250 to \$125, and we have just awakened to the fact that they can be bought abroad for \$85, so it seems to me whoever is getting that rake-off of \$40 will have to stand aside when the orders start to come in a little more briskly. The state of Washington has 45 mines and there are, I think, about 42 helmets distributed through the state, owned by the operators. That is, I guess, the best record of distribution. Illinois is the first state in which the legislature itself has lent its approval to the helmet and has established such stations, and, as I said before, if the man who is in charge of these three stations is interested in his work and can obtain the co-operation of the operators, I believe that during this coming year our eyes will be opened as to the possibilities of the helmet.

However, I never get up to speak without saying that there are limitations to the helmet, and I recognize those as well as anybody else, and when we put a helmet on a new man there is a good deal more trouble than when we go in ourselves, because we know we shall have to go in as far as he did and drag him back. That has happened several times. But that is all by way of experience.

## RECENT EUROPEAN PROGRESS IN DIRIGIBLE BALLOONS.

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BY W. A. BLONCK.

*Presented July 8, 1910.*

The great advance in the construction of dirigibles, or lighter than air machines, on the Continent is more or less due to the encouragement and subsidies given by the various governments, because the successful operation of these machines seems to involve diplomatic advantages in the general concert of the European powers.

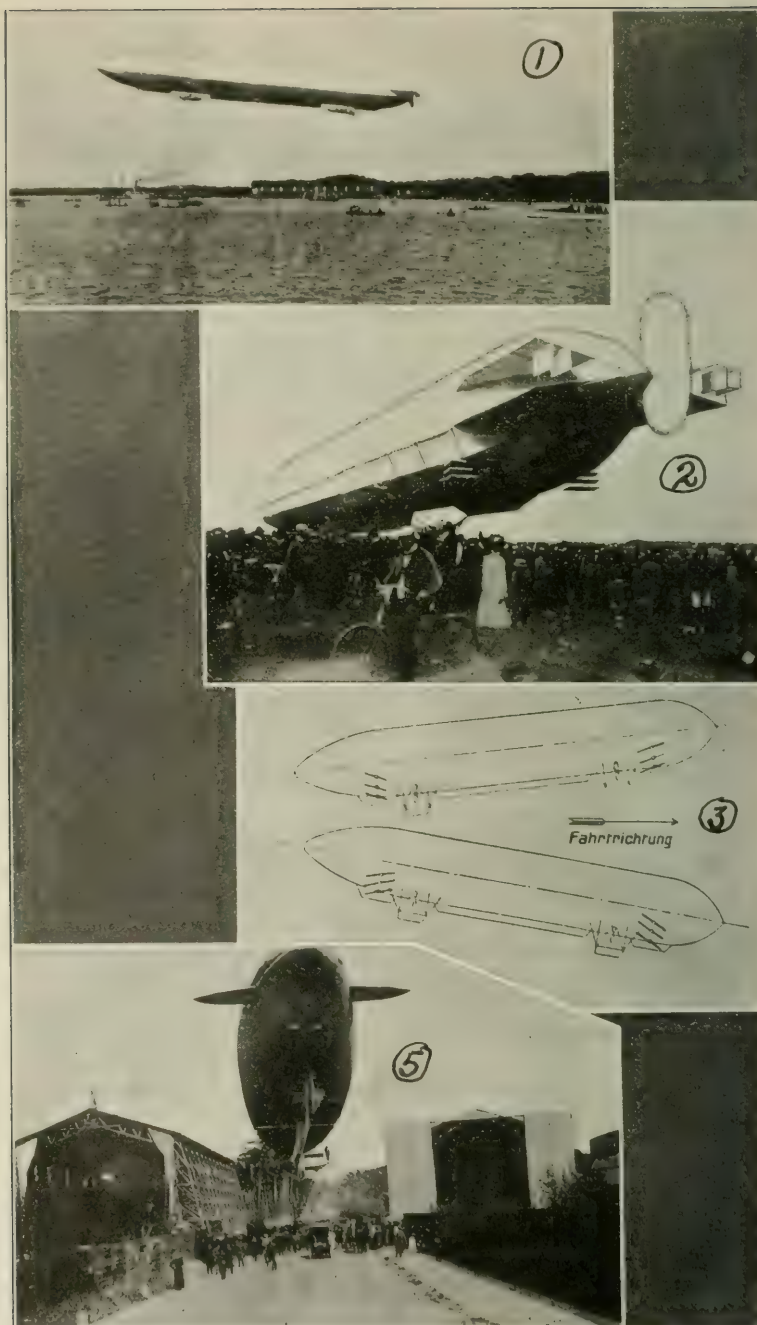
Dirigible balloons were first developed in Europe by the military authorities, and for some time little was made public regarding the progress achieved, as it was deemed a tactical advantage to keep everything secret. As experimentation became more general, however, uses other than military were found for the new craft. The greatest development along this line has been in Germany, where, among others, even the old-established electrical firm, Siemens-Schuckert Werke, has interested itself in various features of dirigible manufacture.

At present three distinct types of dirigible balloons have been developed.

First, the rigid type exemplified by the Zeppelin airships (1). Here the body forms a rigid skeleton, consisting of very light aluminum girder construction and containing a multiplicity of hydrogen bags in separate compartments for the lifting of the airship. The manoeuvring in the vertical plane is effected by a rudder on the stern of the gas bag (2), which is manipulated from the front car, and forms an extension of the rigid stabilization planes, which are attached to the gas bag in order to avoid the rolling of the craft when manoeuvring in an unsteady wind. All motions in the vertical plane are effected either by shifting of a weight between the two cars suspended from the skeleton body or by the operation of two front and two rear louver rudders (3); each of these rudders consists of three planes pivoted in the center, so that an inclined position under speed will cause a rising or lowering of the front part of the ship.

The Zeppelin airships have perhaps received the greatest attention; a number of them have been built at great expense in sizes up to 500 feet long and 40 feet diameter, carrying 32 passengers. Routes have been laid out and companies formed to carry on regular passenger traffic. Between Mannheim and Düsseldorf, in Germany, the stretch has repeatedly been covered in four hours, whereas regular express trains take six hours. A number of unfortunate accidents with the Zeppelin craft, how-

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1. Zeppelin Over Lake Constance.  
 2. Rear Rudder Arrangement of Zeppelin Airship.  
**7. Dirigible Depot at Metz.**  
 5. Airship Gross III. at Tegel.

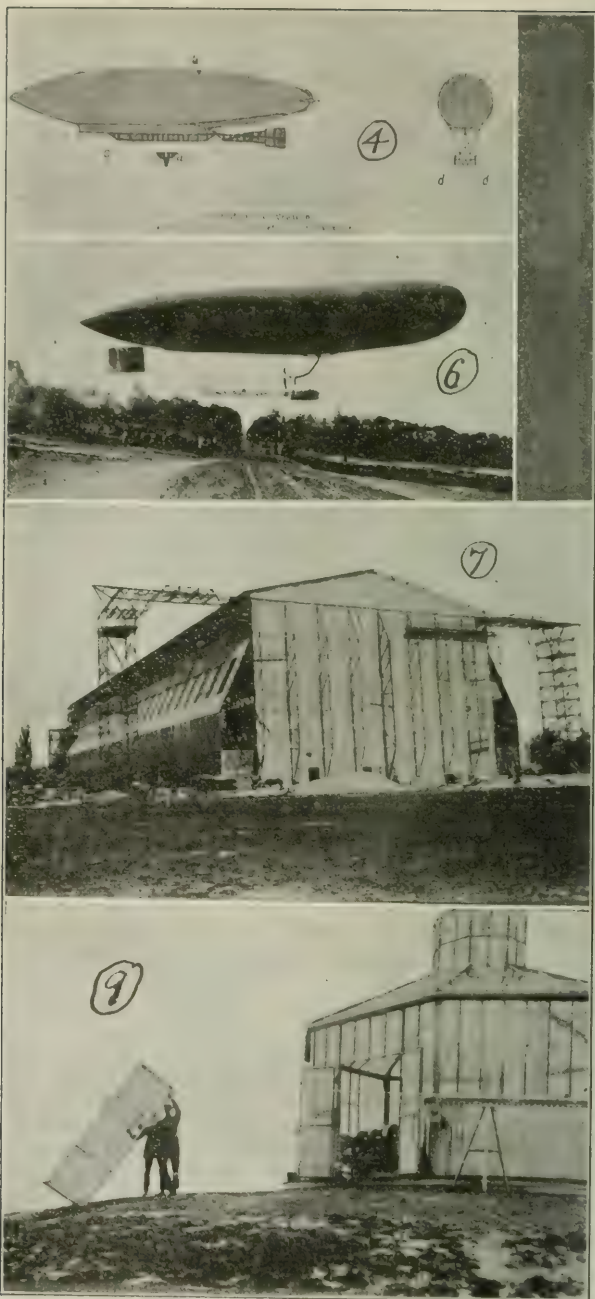
ever, have shown some of the disadvantages of the rigid type of dirigibles.

The second, or semi-rigid, type of dirigible balloons was originated by the designer, Julliot, of LeBaudy Bros., in Paris. It consists of a single gas bag, the suspension wires of which terminate on a rigid keel or girder construction (4), which in turn carries rudders, propellers, and car. This type is used largely in the French and German army. With sufficient engine-capacity in the larger sizes, speeds up to 40 miles per hour in calm weather have been obtained (5).

The third, non-rigid or Parseval, type (6) consists of a large gas bag with cloth reinforcements, from which the car is suspended; the car suspension is flexible, in order to counteract the tilting moment of the propeller, and is so arranged that the axis of the propeller-push coincides with the center of the resulting wind-resistances of the gas bag and car. The gas bag is kept taut by a front and rear ballonnet filled with air under a pressure not exceeding one inch water column; these ballonnets are collapsible compartments inside the gas bag and have a suitable hose connection with a ventilator in the car. By means of this ventilator and three valves, either the front or rear ballonnet can be filled with air, and the weight of such air so transferred parallel to the longitudinal axis of the balloon forms a means of tilting the craft in an upward or downward direction, as it might be desired for the manoeuvring of the dirigible.

The gas bag is made of diagonally woven balloon cloth, consisting of two separate layers of cotton, the weaves of which are placed at an angle of  $45^{\circ}$  and then pasted together by a rubber solution. Cloth of this character withstands a strain of 1000 pounds per running foot. In case of a forced landing on account of gales or bad weather, a rip-cord is attached to the gas bag, which allows an instantaneous release of the hydrogen gas, so safeguarding the bag and car against any further damages from the elements.

For passenger transportation, consisting of radial runs from central points, the results in Germany have demonstrated that the traffic that can be easily secured will greatly exceed any facilities that can be provided. On the lines already established terminal depots (7) have been erected to house and charge the dirigibles, lighthouses (8) have been built with upwardly projecting searchlights to guide them by night, test stations have been constructed with box-kites for determining the direction and velocity of the upper air currents (9), and in other ways the business has been put on a commercial basis. Aside from the established passenger rates, which are rather high as yet, an additional source of revenue has been found from the advertising value of projecting firm names or products on the sides of the gas bag at night (10) when cruising over large cities. For



4. Construction of Semi Rigid Type.

6. Parseval at Bitterfeld.

7. Dirigible Depot at Metz.

9. Weather Observatory at Friedrichshafen.

this service the charge of \$25 per firm per night has been established for showing a name twenty times a night for fifteen seconds at each time.

From reliable sources it is stated that German corporations, either manufacturing dirigibles or interested in the commercial application of them, have at present an aggregate investment of over \$4,000,000, and many of them are to increase their capitalization considerably in the near future.

#### PARSEVAL DIRIGIBLE FOR 20 PEOPLE.

16 passengers, 1 captain, 1 pilot and 2 engineers. Approximate size of gas bag, 300 ft. long and 30 ft. diameter.

Cubical contents of balloon.....240,000 cu. ft.

Cubical contents of ballonets..... 40,000 cu ft.

Maximum hydrogen filling.....200,000 cu. ft.



8. Light Tower at Spandau.  
10. Advertising Display at Berlin.

Maximum lifting-power per 1000 cu. ft. of hydrogen.....70 lb.

Maximum lifting-power per 1000 cu. ft. of coal gas.....45 lb.

Maximum lifting-power of balloon.....14,000 lb.

#### Distribution—

	lb.
20 people .....	3,000
2 125-h.p. motors .....	2,500
2 gasoline tanks .....	2,600
Propellers and ventilator.....	1,000
Car rigging and hull.....	2,000
Ballast .....	2,900

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14,000

Maximum pressure in gas bag, 1 inch water column.

Maximum speed in calm air, 33 miles per hour.

Fuel consumption per mile, 4.25 lb. or 0.5 gallon of gasoline, costing about 5 cents.

#### COST OF HYDROGEN.

Process—	Per 1000 cu. ft.
Zinc and sulphuric acid.....	\$12.00
Iron filings and hydrochloric acid.....	9.00
Iron filings and sulphuric acid.....	4.00
As a by-product, sold in Bitterfeld, Germany....	0.70

The above prices are based on—

Zinc .....	\$4.50 per 100 lb.
Iron filings .....	0.45 per 100 lb.
Sulphuric acid .....	1.00 per 100 lb.
Hydrochloric acid .....	1.00 per 100 lb.

#### APPROXIMATE COSTS, EARNINGS AND OPERATING EXPENSES.

##### Cash investment—

One Parseval dirigible for 20 people.....	\$ 80,000.00
Hall, landing facilities, gas apparatus, projection apparatus for advertising .....	70,000.00
Total.....	<u>\$150,000.00</u>

##### Estimated income—

A. Passenger service; average 150 days annually; 8 runs per day, starting at even hours, averaging 15 passengers, or 120 passengers per day, or 18,000 passengers per year, at average fare \$10.00 .....	\$180,000.00
B. Advertising service; average 150 nights annually; 50 firms at \$25.00 per night; each firm to be displayed 20 times per night for an interval of 15 seconds; 150 runs per year for 50 different displays at \$25.00 .....	187,500.00
Total.....	<u>\$367,500.00</u>

##### Estimated operating expenses—

Crew: 1 captain .....	\$2,000.00
1 pilot .....	1,500.00
2 engineers .....	2,400.00
Also: 1 repair gang .....	4,000.00
30 helpers 150 days at \$2.00 per day.	9,000.00—\$18,900.00

Brought forward .....	\$18,900.00
Gasoline at \$2.00 per hour for 150 days of 12 hours...	3,600.00
4 complete fillings of hydrogen.....	3,000.00
1.5% daily refilling of hydrogen.....	1,500.00
Management, advertising, ticket sales, ground rent and miscellaneous .....	15,000.00
Total.....	\$42,000.00

## IN MEMORIAM.

JAMES C. LONG, M. W. S. E.

Died May 26, 1910.

James C. Long was born at Chattanooga, Tenn., December 2, 1844, and died at Chicago May 26, 1910.

At the age of 15 Mr. Long entered the Naval Academy at Annapolis, Md., as midshipman. When Tennessee seceded in 1861 he resigned from the United States Navy and entered the Confederate States Navy as midshipman, where he continued his education, graduating from the Confederate Naval School in 1863 with the rank of past-midshipman.

Mr. Long served successively aboard the following ships: The gunboat *Curlew*, the iron-clads *Virginia*, *Richmond*, *Savannah*, and *Albemarle*; the blockade runner *Owl* and the steamer *Wren*. The first engagement Mr. Long participated in was the battle of Roanoke Island, where the *Curlew* was sunk, but close enough to land for all the crew to reach shore safely. Other battles in which Mr. Long engaged were the battle of Hampton Roads, where, aboard the *Virginia*, he participated in the famous duel between the *Merrimac* and the *Monitor*; the battle of Drury's Bluff, a land-naval battle, in which with guns dismantled from their fleet, the Confederate sailors and marines repulsed the Union fleet from a fort improvised on the right bank of the James river, a few miles below Richmond; the sinking of the *Albemarle*—although not properly speaking a battle—where the Confederate iron-clad was sunk by a torpedo impelled from a launch by Lieutenant Cushing and his men; and the battle of Plymouth, off the coast of North Carolina—his last battle.

At the close of the war Mr. Long, now promoted from past-midshipman to master, found himself in command of his vessel, being the highest ranking officer aboard. In attempting to run her to England, an unwilling crew captured all the officers while asleep in their staterooms, and turned them over to the Union forces at Key West, Fla., where Mr. Long was detained for a few days as a prisoner of war and then allowed to return to his home.

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Shortly after the war Mr. Long's political disabilities were removed by Act of Congress, and he went to work as draughtsman in the quartermaster department of the United States government. Thenceforward he pursued the calling of civil engineer. He worked successively for the Alabama Great Southern Railway, for the Government under Major Walter McFarland on the Muscle Shoals Canal; for the East Tennessee, Virginia and Georgia Railway; for the Government under Major Amos Stickney at New Orleans, and under Capt. H. S. Tabor at Little Rock; as superintendent of public works at Birmingham, Ala.; for the Government under Capt. W. H. Bixby at Wilmington, N. C.; for the Macon and Birmingham Railway, and for the last seventeen years of his life as assistant engineer for the Government on the Illinois and Mississippi Canal, under Major W. L. Marshall, Major J. H. Willard, Major C. S. Riché, and Col. W. H. Bixby. Mr. Long began his surveys for the eastern section of the canal early in 1893, establishing permanent marks, making borings, and acquiring right-of-way. The first contract for earthwork on the eastern section was let on September 1, 1894. Work on bridges and culverts followed soon after, and on the first lock in April, 1895. Thereafter work was carried on as fast as the appropriations and legal delays would permit. This section includes 28 miles of earthwork, 21 locks, 15 pipe culverts, 9 arch culverts, 3 aqueducts, 19 highway bridges and 3 railroad bridges—costing more than \$3,000,000. The masonry for locks, culverts, aqueducts, and bridges was built of concrete and played an important part in the remarkable development of concrete construction during that period. Water was turned into the canal during the fall of 1907, and from that time until his death Mr. Long was in charge of the operation and maintenance of the works which he had built during the preceding thirteen years.

Mr. Long was married on November 20, 1872, at Elyton, Ala., to Miss Fannie Walker, of Elyton. He survived his wife by eight years and is survived by four sons and one daughter—Wm. W. Long, John P. Long, James C. Long, Jr., Mary C. Long, and Crawford J. Long, all of Birmingham, Ala.

Mr. Long was a Royal Arch Mason, a member of Camp Forrest, United Confederate Veterans—which camp is situated at Chattanooga, Tenn.—and has been a member of the Western Society of Engineers since September 7, 1895. He was a man of sterling character, faithful and loyal to his superiors, genial and courteous to his subordinates. He was a Southern gentleman of the old school, modest and retiring in his disposition, but always beloved by those who were fortunate enough to gain his acquaintance.

G. A. M. LILJENCRANTZ,	} Committee.
F. W. HONENS,	
J. W. WOERMANN,	

Vol. XV. No. 5

# PROCEEDINGS OF THE SOCIETY.

## ABSTRACT OF THE MINUTES OF THE MEETINGS.

*Wednesday, September 7, 1910.*—A special meeting of the Society (No. 708) called to create and organize a Hydraulic, Sanitary, and Municipal Section, met at 4:30 p. m., President Alvord presiding with nineteen members and guests present. The Chairman explained that the calling of the meeting was in accordance with the By-Laws and on the petition of fourteen Active members of the Society, had been authorized by the Board of Direction, August 2d. Favorable responses had been received from over seventy members of the Society as to their interest in such a Section. Past-President Benezette Williams was elected temporary chairman. Mr. John Ericson was elected Chairman, L. K. Sherman, Vice-Chairman, C. B. Burdick, T. C. Phillips, and W. S. Shields, members of the Executive Committee. The Executive Committee was authorized to prepare a set of rules and regulations for the governing of the Section. Meeting adjourned at 5:30 p. m.

*Wednesday, September 7, 1910.*—Regular meeting (No. 709) called to order at 8:20 p. m., President Alvord presiding with thirty members and guests in attendance. The Secretary reported that the following had applied for membership:

Ludwig Kemper, Oak Park, Ill.  
Edwin L. Ryerson, Chicago.  
R. W. Eichenberger, Chicago.  
Wm. E. Ramsey, Chicago, transfer from Junior.  
Jean Bart Balcomb, Chicago.  
Edmund T. Perkins, Chicago.  
Edward N. Roth, Chicago.  
W. W. DeBerard, Chicago.  
Daniel K. Van Ingen, Friendship, Wis.  
Chason W. Brooks, Chicago, transfer from Junior.  
Bernard C. Groh, Chicago.  
Henry L. Kellogg, Clearing, Ill.  
Julius G. Gabelman, Chicago.  
Horace C. Hawkins, Oskaloosa, Iowa.  
Albert H. Gregersen, Chicago.

Also that the following had been elected into membership:

F. W. Kassebaum, Chicago.....	Active
W. M. Kallasch, Chicago.....	Active
Grant Ford, Chicago.....	Active
Edwin S. Mills, Chicago.....	Associate
Ludwig Kemper, Oak Park, Ill. ....	Active
Frank W. Hillman, Chicago, transfer from Junior.....	Active
Edwin L. Ryerson, Jr., Chicago.....	Junior
Wm. E. Ramsey, Chicago, transfer from Junior.....	Active
R. W. Eichenberger, Chicago.....	Junior
Edmund T. Perkins, Chicago.....	Active
Edward Cannell, Lubbock, Texas.....	Active
Jean Bart Balcomb, Chicago.....	Active
W. W. DeBerard, Chicago.....	Active
Chason W. Brooks, Chicago, transfer from Junior.....	Active
Henry L. Kellogg, Clearing, Ill. ....	Active
Julius G. Gabelman, Chicago.....	Active
Donald H. Maxwell, Chicago.....	Junior

The Secretary announced the death, August 21, 1910, of J. J. McVean, of Grand Rapids, Mich.

October, 1910

J. B. Sando, of Milwaukee, read his paper on High Pressure Water Service for Fire Protection, with stereopticon illustrations. Discussion followed from Messrs. Alvord, Scheible, Mayer, Grant, and Baker. Meeting adjourned at 10:30 p. m.

*Wednesday, September 14, 1910.* Informal meeting (No. 710) and smoker. Mr. A. Reichmann presided with about seventy-five members and guests present. Mr. W. R. Patterson gave an informal talk with stereopticon illustrations of views in Japan after which refreshments were served. Adjourned at 10:30 p. m.

*Wednesday, September 21, 1910.*—Extra meeting (No. 711) and Eighth meeting of the Bridge and Structural Section; called to order at 8:15 p. m. with T. L. Condron presiding and ninety members and guests in attendance.

The proposed new Building Ordinance of Chicago was presented and discussion followed on Dead and Live Loads and Wind Pressure; Foundations and Bearings on Soil; and Pile Bearings, from Messrs. Lawry, Armstrong, Vent, McCullough, Green, Davidson, Giaver, Sawyer, Basquin, Fixmer, Martin, Smetters, Cowles, Strehlow, and Gerety.

Resolution offered and passed to ask the Board of Direction to appoint a committee to consider the scheme of organization of the Building Department of the City, and that a committee of three be appointed by the Chair to present this resolution to the Board of Direction. The committee appointed consisted of Messrs. Giaver, Davidson, and Gerety. Meeting adjourned at 10:30 p. m.

*Wednesday, September 28, 1910.* Extra meeting (No. 712) of the Society called to order at 8:30 p. m., President Alvord presiding, and thirty members and guests present.

Mr. Alfred S. Johnson of the Radford Architectural Co., gave an informal address, with stereopticon illustrations, on New Light on the Origin of Portland Cement. A vote of thanks was tendered Mr. Johnson for his address. Meeting adjourned at 9:50 p. m.

*Wednesday, October 5, 1910.* Regular meeting (No. 713) called to order at 8:30 p. m. with President Alvord presiding and seventy-five members and guests present.

Minutes of previous meetings read and approved. The Secretary reported the following list of applicants for membership:

Winfred D. Gerber, Chicago.  
George L. Thon, Chicago.  
Orville H. Drought, Chicago.  
Langdon Pearse, Chicago.  
Harry W. Myers, Chicago.  
Lawrence V. Fraley, Chicago.  
John M. Davidson, Gary, Ind.  
Edwin Hancock, Jr., La Grange, Ill.  
Wilhelm Warnecke, Chicago.  
George C. D. Lenth, Chicago.

And that the following had been elected Active members:

D. K. Van Ingen, Friendship, Wis.  
Bernard C. Groh, Chicago.  
Horace C. Hawkins, Oskaloosa, Iowa.  
W. D. Gerber, Chicago.  
George L. Thon, Chicago.

The following resolutions were submitted to the Society and voted on in the affirmative:

WHEREAS, a new building ordinance for the City of Chicago is now under consideration in the City Council, part of which ordinance deals with the reorganization of the Department of Buildings; and,

WHEREAS, the Western Society of Engineers believes that an

efficient organization should include a proper arrangement of the force operating under it, and the provision of means to fix the duty, responsibility, and authority of each person in such force; and,

WHEREAS, we believe that such an organization should have an efficient head, sub-heads, and subordinates, in order to be effective, and;

WHEREAS, we believe that in view of the enormous volume of work submitted to the Building Department for approval, the present organization, especially as regards the engineering assistance, is entirely inadequate to properly safeguard the public's interest; and,

WHEREAS, a special committee appointed by the Board of Direction has reported favorably on the aforesaid ordinance, and has recommended that the Western Society of Engineers take strong and immediate action in favor of the same;

THEREFORE, BE IT RESOLVED, that in the opinion of this Society those sections of the proposed building ordinance dealing with the reorganization of the City Building Department should provide for an organization which would at least meet the present needs of this department; and,

BE IT FURTHER RESOLVED, that the Western Society of Engineers hereby endorses those sections of the proposed ordinance relating to the organization of the Department of Buildings, and hereby respectfully requests the City Council to enact same into law; and,

BE IT FURTHER RESOLVED, that a copy of these resolutions be spread upon the records of the Society, and that a copy of same be transmitted to Mayor Busse, and to each member of the City Council of the City of Chicago, and to the daily press.

W. L. Abbott,  
Andrews Allen,  
Horace E. Horton,  
W. H. Finley,  
C. F. Loweth,

Ralph Modjeski,  
Isham Randolph,  
E. C. Shankland,  
John M. Ewen,  
J. G. Giaver,

Committee.

The Amendment Committee presented a draft of proposed amendments to the Constitution and By-Laws which were ordered printed and sent out to the membership, to come before the Society at its regular November meeting.

The address of Mr. B. E. Sunny, January 12, 1910, "Engineering of Chicago," was presented. As this was a municipal matter the meeting became the first of the Hydraulic, Sanitary, and Municipal Section, and was further conducted by Mr. John Ericson, Chairman of that Section. An abstract of Mr. Sunny's address was given by Mr. Wray; discussion followed from Messrs. Finley, Symons, Davidson, Bernard Mullaney, Mershon, Allen, Ashley, Clausen, Baker, and Bement. Also by letter from E. L. Corthell and A. S. Robinson. Adjourned at 10:30 p. m.

Wednesday, October 12, 1910. Extra meeting (No. 714), the Ninth meeting of the Bridge and Structural Section, was called to order at 8:15 p. m., Mr. T. L. Condron presiding and sixty-five members and guests present.

Minutes of meeting, September 21st, read and approved. Subject for discussion was the "Allowable Unit Stresses in Building Material," of the proposed Building Ordinance of Chicago. *Piles and Foundations* were discussed by Messrs. Strehlow, Condron, McCullough, and Armstrong; *Timber*, by Messrs. Davidson, Winslow, Allen, and Strehlow; *Structural Steel*, by Messrs. Armstrong, Condron, Allen, and Dart.

On motion, it was voted to adjourn the meeting to Monday evening, October 17, for further consideration of masonry and reinforced concrete. Adjourned at 10:30 p. m.

October, 1910

Monday, October 17, 1910. Extra meeting (No. 715), Tenth meeting of the Bridge and Structural Section, adjourned from October 12th, for further discussion of proposed Building Ordinance for Chicago.

Called to order at 8:20 p. m. with T. L. Condron presiding and sixty members and guests present. *Masonry and Concrete*, subject for discussion. J. G. Giaver presented his views on masonry, by letter, and further discussion was offered by Messrs. McCullough, Hoyt, Dodge, Armstrong, Martin, Gerety, Davidson, Finley, Cowles, Langenheim, Allen, Grossman (of New York), and the Chairman. Meeting adjourned at 10:20 p. m.

J. H. WARDER, Secretary.

## BOOK REVIEWS.

**ENGINEERING CHEMISTRY.** A Manual of Quantitative Chemical Analysis for the use of Students, Chemists, and Engineers. By Thomas B. Stillman, M. Sc., Ph. D. The Chemical Publishing Co., Easton, Pa., 1910. 4th ed. Cloth, 6 by 9 in.; pp. 744; 174 illustrations. Price, \$5.00.

This is a very practical book on the analysis of those materials with which the engineer in his professional work is most interested. Beginning with approximate analysis of coal and coke, this is followed by the analysis of limestone and the determination of phosphoric acid in compounds of phosphate of lime. The value of this is in deciding upon the fertilizing value of a phosphatic rock or other compound.

The determination by various processes of the iron in iron-ores and the analysis of furnace slags is next presented, and there follows the analysis of other ores, as manganese, copper, zinc, and lead.

Water and its impurities, whether they are of a mineral or of organic character, are matters of prime importance in our daily life, and some 50 pages are devoted to the consideration of boiler waters, the hardness of waters, the sanitary character, and the filtration of water; also water for locomotive work.

Feed water heaters and their action naturally follows here, with a consideration of fuel economizers and the determination of the heating power of coal and coke. The subject of calorimetry and analysis of gases comes in here, with a consideration of the heating value of combustible gases, and the manufacture of water gas, etc., with a description of a gas calorimeter.

Practical Photometry and Liquid Fuel next follows, with the valuation of coal for gas manufacture.

Blast Furnace operations, the graphic method of determining blast furnace charges, the value of the waste gases as a source of power, the sampling of iron ores, and foundry chemistry are all matters of great importance, and receive due consideration.

Hydraulic Cements receive their share of attention, with instructions in their chemical and physical examinations, the composition of natural cements, and analyses of clay, and fire sand. These are followed with physical tests of stone and bricks. Asphalt has generous consideration, though not more than its importance demands.

The chemical and physical examination of paper occupies more than twenty pages, and nearly 30 pages are given to Alloys—composition and analysis. Other subjects are Soap Analysis, Petroleum, Lubricating Oils, Paint Analysis, Acetylene, Pyrometry, etc.

The book is well gotten up, though some of the illustrations are not as clear and well made as they could have been if worked up from original sources instead of old engravings. Many tables and formulae are introduced through the text, and specifications for composition, quality, etc., of various substances are appropriately introduced. Altogether, the work is a valuable one and well worth a place in an engineer's library, but it must be understood that the practical use of this book necessitates some knowledge of chemistry and some little experience in chemical manipulation. W.

**SEWERAGE.** The Designing, Construction and Maintenance of Sewerage Systems. A. Prescott Folwell, Member, American Society of Civil Engineers, Editor *Municipal Journal and Engineer*, 6th ed.; revised and enlarged New York, 1910. John Wiley & Sons. Cloth, 6 by 9 in., 506 pages, including index, with many plates and illustrations. Price, \$3.00.

It is a pleasure to welcome this book in its enlarged and improved form after one has made use of and proved the value of the earlier editions. The book has a decided value to the engineer engaged in iron work, and also has been so prepared as to be a valuable text-book for use by professors and students in the engineering schools. The book is divided into four parts: I, Designing; II, Construction; III, Maintenance, and IV, Sewerage Disposal. These are further sub-divided into a series of twenty-six chapters.

Chapter I—The System, which includes the Dry Sewage, the Pneumatic Systems and Water Carried Systems, whether combined or separate systems.

Chapter II, treats of Amount of Sewage, including House Sewage Flow, Storm Water, Rates of Rainfall, Run-off Data, and expediency of providing for excessive storms.

Chapter III, considers Flow in Sewers, based on limits of velocity and the size and shape of sewers.

Chapter IV, pertains to Flushing and Ventilation; discusses necessity for flushing; methods and appliances for same, and ventilation, necessity and methods.

Chapter V, collecting the data for design and includes surveying and plotting.

Chapter VI, The Design, includes General Principles, Districts and Sewer Lines, Volumes of House and Storm Sewage, Grade—Size and depth of sewers; House and Inlet Connections; Pumping Sewage, etc.

Chapter VII, is of Detail Plans, while Chapter VIII is of Specifications, Contracts and Cost Estimates, concluding with Methods of Assessment.

Part II, Construction, takes up the practical questions involved as contract work or day labor, preliminary engineering work, etc., and in Chapters X and XI is considered Laying Out the Work, with duties of the engineer, measurements and final inspection.

Chapter XII treats of Practical Sewer Construction, and is a valuable one for its instruction in the practice of trenching, excavating, sheathing, laying pipe sewers, masonry construction, manholes, handling work in wet ground, making crossings, outlets, etc.

Part III, Maintenance, is of the House connections and drainage in Chapter XIII, and of Sewers, including flushing and cleaning, in Chapter XIV.

Part IV consists of Chapters XV and XVI on Sewage Disposal, whether by dilution or otherwise, and Methods of Treatment. This part of the book is new in this edition.

It speaks well of this book and how it is regarded by the engineering profession that in the short space of time, of about eleven years, the book is now in its sixth edition, and that about 1,100 copies have been disposed of.

The reviewer, having made practical use of earlier editions of this book, feels justified in commending it highly. W.

**THE RAILWAY LIBRARY.** 1909. A collection of noteworthy chapters, addresses and papers relating to railways, mostly published during the year. Compiled and edited by Slason Thompson. Bureau of Railway News and Statistics, Chicago. Cloth, 5½ by 8½ in.; pp. 403, including index.

The readers of the *JOURNAL OF THE WESTERN SOCIETY OF ENGINEERS* may remember the interesting and forceful plea for justice to the railroads, made before the Society at the Annual Dinner January 5, 1909, by Mr. Frank Trumbull, then President of the Colorado and Southern Railway Company, and which was published that year (Vol. XIV. page 18). That address

appears in this volume, with addresses, speeches, etc., from other notable men who have been and are identified with railroad interests. Among these is our own Past President, John F. Wallace, who addressed the Southern Commercial Congress in Washington, December, 1908, on southern railways and their needs.

The volume opens with an interesting historical study of the conditions in this country in early days—"Pre-Railway Era in America," by Messrs. Cleveland and Powell. The next chapter goes back to 1848 and is the First Annual Report of the Chief Engineer (J. Edgar Thompson) of the Pennsylvania Railroad Company. That was not so very long ago—sixty-two years—but to those who know that magnificent railroad between Pittsburg and Philadelphia, it is a revelation to read and consider this report.

Then comes the address of James J. Hill at Portland, Tacoma and Seattle early in November, 1908, on the completion of the Spokane, Portland & Seattle Railway, under the title of "Railways and the Pacific Northwest." This address is a notable one, and attracted a good deal of attention when delivered.

Other papers are "Problems Confronting American Railways," by Daniel Willard, Second Vice President of the "Burlington;" "Progressive Safety in Railway Operation," by A. H. Smith; "Railway Mail Pay," by Julius Kruttschnitt; "The Railroads and Public Approval," by Edward P. Ripley, etc. Two of the papers are by Englishmen, "The Relation of the Railroads to the State," by W. M. Acworth, and "Railway Nationalization," by Sir George S. Gibb.

These papers are all special pleas for the railroads, and are interesting reading even if one is not biased in favor of the railroads and may not be entirely convinced by the arguments presented. W.

**THE WELLBEING OF WATERLOO.** A Report to the Civic Society of Waterloo, Iowa, by Charles Mulford Robinson, Rochester, N. Y. Pam. 6 by 9 in., pp. 39, two maps and numerous illustrations. April, 1910.

The author of this report is the author of two high grade books which have been reviewed and commended in the pages of the *Journal* of this Society. These are, "Modern Civic Art, or The City Made Beautiful," and "The Improvements of Towns and Cities," both published by Putnam, New York.

This report is along these same general lines toward beautifying a prosperous country town which has some great natural advantages, built as it is on the Cedar River, and with the benefit of being in the midst of a rich agricultural region. Its inhabitants are probably above the general average in intelligence and possession of ideals, but through one or another cause, which can be classed under ignorance, or indifference, many things were permitted which made for ugliness in the town. The author, while commending much that is good, points out some shortcomings and then shows what can and should be done to improve the good things they have in the way of parks, the water front, the City Hall and its setting, the railroads and how to improve their appearance, etc. The book is beautifully printed and should be a spur to the civic management and improvement of many other communities. W.

**THE BLUE BOOK.** Containing information and tables relative to the use of Pittsburgh Standardized Reinforcement for Concrete, for Architects, Engineers and Builders. Published by the Pittsburgh Steel Products Company, Pittsburgh, Pa.

This little handbook, 4½ by 6½ in., leather bound, containing 397 pages (including index), is essentially a trade publication, though prepared at considerable cost and under the oversight of William Barclay Parsons, Consulting Engineer. The tables are assumed to be correct and are of value in assisting the design of reinforced concrete work—girders, beams, slabs, etc.—but based upon the use of the special form of bars to be furnished by the

Pittsburgh Steel Products Company. However, as the sectional area of these special bars is tabulated, by a little extra work in calculating and substituting, the tables pertaining to reinforced concrete slabs, beams, etc., can be used for other forms of reinforcement. But the tables as they are, show great industry on the part of the compilers in working them up for ready reference. As an idea of the magnitude of the work, there are two tables, covering 134 and 59 pages of the book, and furnish the necessary data for reinforced concrete beams and slabs for spans up to 30 ft., floor loads up to 400 lb. per sq. ft., and total loads up to 340 tons. A good many other tables are introduced, which enhance the value of the book, such as conversion tables, weights of substances, timber beams, mensuration, trigonometry, etc., etc.

The book is very neatly printed and bound, and is of value to those engaged in reinforced concrete design and construction. W.

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### TRADE CATALOGUES.

THE KENYON TAKE-DOWN HOUSE. R. L. Kenyon Co., Waukesha, Wis., 6 in. by 9 in., 36-page pamphlet.

This pamphlet describes the construction of this make of portable houses suitable for summer camps, for engineers and contractors' use, etc. The house consists of a frame made of seasoned yellow pine, with an ingenious arrangement of clamps so it can be put up without cutting, fitting or nailing. The roof, walls and partitions are made of specially prepared heavy duck of a brown color with awnings of same for porches. Windows and doors of the same material afford lightness. Light is admitted through a flexible and transparent medium (presumably of celluloid) which will not break. There are no sash and glass to break, but the windows can be opened or closed against stormy weather. A wooden floor is provided. The arrangement seems to be admirable. The houses are made in seven standard sizes. The 18 ft. by 30 ft. size consists of two chambers, one large living-room and a porch at one end from which a part is curtained off for a kitchen, and the remainder can be used for an outside dining-room. The price of this, complete, is \$350.00. Smaller sizes are planned, down to a one-room cabin, 7 ft. by 9 ft., suitable for a miner or hunter, weighing 280 lb. and costing only \$50.00. The catalogue also shows a variety of furnishings, as portable cots, stools, and chairs, suitable for use in such camping outfits. These lines seem admirably adapted for summer camps, and also for a semi-temporary camp for surveying parties and the like, possessing the great merit that the house can be readily taken down, transported to a new location, and then erected with but little labor. They are much more convenient and cooler in mid-day and give better protection during rainstorms than the usual duck tents.

The R. L. Kenyon Company are to be congratulated on the completeness of their design and good quality of their manufacture. W.

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HANDLING COAL. Jeffrey Bulletin No. 42; 6 in. by 9 in., 48 pages.

This finely illustrated pamphlet is devoted to coal handling and mine equipment. The first ten pages, with a number of good illustrations from photographs, show the product of the Jeffrey Company in the line of coal tipples designed by and built under the supervision of their engineers, the plans showing some modifications to suit special conditions. One of the notable installations shown is the 5,000-ton steel tippie for the Empire Coal and Coke Company at Landgraff, W. Va. The tippie spans four loading tracks and the coal is conveyed, sized, picked, mixed as may be desired, and loaded into cars with practically no breakage, though the coal is of a very soft grade of Pocahontas.

October, 1910

Other conveying machinery of the Jeffrey make adapted to handling coal is shown, as retarding conveyors for delivering coal from an upper to a lower level, using pan carriers or chain scrapers, as may best serve the conditions.

In Bulletin No. 42 other Jeffrey machinery is shown, as mine cages, jigs and other machinery for washeries, locomotive coaling stations, conveyors of various designs and for different service; also derricks with grab buckets for unloading coal from barges and the like. Another line of manufacture of the Jeffrey Company is that of fans for mine ventilation, screens for sizing coal, whether of rotary, shaking, or of fixed-bar type, crushers of various types and pulverizers for reducing coal, shale, limestone, etc., to powder.

Hoists, cars, and larries of various design are presented, as well as coal cutters, drilling machines, etc. Anyone interested in such machinery can get this Bulletin No. 42 by applying to the Jeffrey Company, Columbus, Ohio.

Booklet No. 28, just issued by the same company, is of small size and convenient for frequent reference, describing as it does a variety of conveying machinery for handling stone, sand, gravel, ores, etc. It can be had for the asking.

W.

#### SULLIVAN MACHINERY Co., Chicago.

*Bulletin No. 58 D.* Tandem Corliss Air Compressor. This describes the new type of air compressor, class WC, of high-grade construction, with Corliss valves giving great steam economy. The arrangement of valves and general construction is described in considerable detail with several well executed engravings. A table of dimensions and capacities shows the range of sizes of this line of machinery.

*Bulletin No. 58 F.* describes the Sullivan Small Air Compressors, power driven by belting, or with a chain drive from an electric motor. This publication shows the construction by illustrations and descriptions of classes WG-3 and WG-4, WK, WK-2 and WK-3. There is a table of dimensions and capacities of this line of machinery.

*Bulletin No. 58 G.* describes power driven classes WJ, WI, WN and the steam driven classes WE and WF, which are duplex machines of high efficiency, yet at a moderate price. The design and construction of these machines is admirable. The machines are self-contained, mounted on a substantial base, thus enabling them to be set up on a cheaper and more temporary foundation. Two pages of tables show the various sizes and capacities of these machines.

All of the above machines are of the highest grade of workmanship and possess many advantages. The great and constantly growing use of air under pressure, for use in mines, quarries, for pumping outfits, and in many other places, shows a market for such machinery. The book-work of these bulletins is first-class, as would naturally be expected from the Sullivan Machinery Company.

W.

## LIBRARY NOTES.

The Library Committee desires to return their thanks for donations to the Library. Since the last publication of the list of such gifts, the following publications have been received:

### MISCELLANEOUS GIFTS.

- Charles J. Poetsch, M. W. S. E., Milwaukee, Wis—  
Annual Report of City Engineer, Milwaukee, 1909. Cloth.
- Chicago Commission of City Expenditures—  
Report on Building Department. Report on McGovern  
Street Repair Contract. Report on Purchase of Lum-  
ber, etc. Report on The Police Department. Pams.
- Michigan College of Mines—  
Year Book 1910, List of Graduates and book of views.  
Pams.
- John Wiley & Sons, New York—  
Sewerage, by A. P. Folwell. Cloth.
- McGraw-Hill Book Co., New York—  
Railway Special Work, by Silsbee and Blood. Leather.
- Charles M. Robinson, Rochester, N. Y.—  
The Wellbeing of Waterloo, Iowa. Pam.
- Underwriters' Laboratories, Chicago—  
The Object of Tests and Investigations, etc. Pam.
- Tennessee State Geological Survey, Nashville, Tenn.—  
Bulletins of State Geological Survey. 3 Pams.
- Pittsburgh Steel Products Co., Pittsburgh, Pa.—  
Concrete Reinforcement. Leather.
- New Orleans Sewerage and Water Board—  
Twentieth Semi-Annual Report. Cloth.
- Illinois Bureau of Labor Statistics—  
Twenty-eighth Annual Coal Report. Cloth.
- McGraw Publishing Co., New York—  
The McGraw Electrical Directory, Aug., 1910. Leather.
- Chemical Publishing Co., Easton, Pa.—  
Engineering Chemistry, Stillman. Cloth.
- Slason Thompson, Chicago—  
The Railway Library, Thompson. Cloth.
- Baltimore Sewerage Commission, Baltimore, Md.—  
Annual Report, 1909. Pam.
- Ohio State University, Columbus—  
Bulletin, Department of Civil Engineering, Vol. XIV, No.  
3. Pam.
- City of Providence, R. I.—  
Annual Report of the City Engineer, 1909. Pam.
- C. L. Strobel, M. W. S. E., Chicago—  
Various Reports of the National Monetary Commission.  
Pams.
- The Macmillan Co., New York—  
The Conservation of Natural Resources in the U. S., Van  
Hise. Cloth.

- Bion J. Arnold, M. W. S. E., Chicago—  
Second Annual Report of Board of Supervising Engineers.  
Cloth.
- George A. Damon, M. W. S. E., Pittsburg—  
The City and the Allegheny River Bridge, Pittsburg. Pam.
- Masons' & Contractors' Association, Chicago—  
Official Directory and Guide, 1910. Leather.
- Frederick J. Prior, Chicago—  
Construction and Maintenance of Railway Roadbed and  
Track, Prior. Leather.
- New York Board of Water Supply—  
Third Annual Report, 1908. Cloth.
- Engineering News Publishing Co., New York—  
General Specifications for Structural Work of Buildings,  
Schneider. Pam.
- Illinois Water Supply Association, Urbana, Ill.—  
Proceedings, Second Meeting, 1910. Cloth.

## EXCHANGES.

- American Society of Civil Engineers, New York—  
Transactions, Sept., 1910. Paper.
- American Electrochemical Society—  
Transactions, 1910. Paper.
- American Institute of Electrical Engineers—  
Transactions, 1909. Cloth.
- Western Australia Geological Survey—  
Bulletin No. 33, Geological Investigations. Bds.
- Institution of Civil Engineers, London—  
Proceedings, July, 1910. Paper.
- Boston Society of Civil Engineers—  
Proceedings, 1879-81, cloth. Monthly Bulletin Nos. 1-37.  
Cloth.
- Nova Scotia Institute of Science—  
Proceedings and Transactions, Part II, 1907-8. Pam.
- University of Kansas—  
Science Bulletin, Vol. XI, No. 7. Pam.
- Institution of Mechanical Engineers, London—  
Proceedings, 1910, No. 1. Paper.
- Institution of Naval Architects, London—  
Transactions, 1910. Cloth.
- Western Railway Club, Chicago—  
Proceedings, 1909-10, Vol. XXII. Cloth.
- Northeast Coast Institute of Engineers and Shipbuilders, London—  
Transactions, 1909-10, Vol. XXVI. Cloth.
- University of Illinois Water Survey—  
Bulletin No. 7. Cloth.
- University of Wisconsin, Madison—  
University of Wisconsin Bulletins. 14 pams.

## GOVERNMENT.

- U. S. Geological Survey—  
The Production of Mineral Paints in 1909. Pam. The  
Production of Glass Sand, Other Sand and Gravel in  
1909. Pam. The Production of Monazite and Zircon  
Vol. XV. No. 5

in 1909. Pam. Coal Briquetting in 1909. Pam. The Cement Industry in the United States in 1909. Pam. Bulletins Nos. 415, 432, 427, 425. Geological Atlas Nos. 171, 173.

U. S. Bureau of Census—

Religious Bodies in 1906, Parts I and II. Cloth. Central Electric Light and Power Stations, 1907. Cloth

U. S. Civil Service Commission—

Sixth Report, 1888-9. Cloth.

Library of Congress—

Classification, Class T, Technology. Pam.

## MEMBERSHIP.

### Additions to Membership:

Edward Cannell, Lubbock, Texas.....	Active
Jean Bart Balcomb, Chicago.....	Active
W. W. DeBerard, Chicago.....	Active
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Bernard C. Groh, Chicago.....	Active
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George L. Thon, Chicago.....	Active

### Deaths:

June 14, 1910, George N. Eastman, Palm Springs, Cal.  
August 21, 1910, John J. McVean, Grand Rapids, Mich.

### Changes of Address:

Bates, William S., 269 Dearborn St., Chicago.  
Black, Robert M., 1327 Corcoran St., Washington, D. C.  
Bradshaw, Grant D., Cambria Steel Co., Johnstown, Pa.  
Case, James F., The Cuban Engineering Co., Havana, Cuba.  
Cochrane, Hayward, Antrim, N. H.  
Budd, Ralph, Ch. Engr., S. P. & S. Ry., Portland, Ore.  
Decker, H. H., Winona, Minn.  
Henderson, C. E., 358 Ambrose St., Port Arthur, Ont.  
Kellogg, W. H., Jr., 31 E. 27th St., New York.  
Plessner, Otto C., 244 W. 122d St., New York.  
Putnam, L. J., Tunnel City, Wis.  
Wilson, J. M., Pierre, S. D.  
Wright, Joseph, Ronan, Montana.

# WESTERN SOCIETY OF ENGINEERS

SECRETARY'S OFFICE, LIBRARY, READING ROOM AND ASSEMBLY HALL,  
1735 Monadnock Block, Chicago.

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W. W. CURTIS.....	Term expires January, 1913
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The above named officers of the Society and three past presidents  
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J. H. WARDER

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## MEETINGS

Regular Meeting—First Wednesday evening of each month except January, July and August.

Bridge and Structural Section—Generally the second Wednesday of the month.

Extra Meeting—Third Wednesday evening of the month except July and August.

Electrical Section—Generally the fourth Wednesday evening of the month.

Board of Direction—The Tuesday preceding the first Wednesday of each month.

## NOTICE

From the dues of each member, \$2.00 is set aside as a subscription to the JOURNAL.

# Journal of the Western Society of Engineers

VOL. XV

DECEMBER, 1910

No. 6

## THE DESIGN OF STORM WATER DRAINS IN A MODERN SEWER SYSTEM\*

Jean Bart Balcomb.

*Presented May 18, 1910.*

### OUTLINE.

#### GENERAL FEATURES OF THE PROBLEM.

*Hydraulic engineering and the city water problem.*  
*The city water problem and storm drains.*  
*A three-fold view of the question.*  
*Essentials of a good system.*  
*Disposing of sewage.*  
*The separate or combined system.*  
*Estimating the amount of sewage.*

#### NECESSARY ASSUMPTIONS AND APPROXIMATIONS.

*Typical sewer lengths.*  
*Surcharge periods.*  
*Permeability of surface.*  
*Surface concentration.*

#### A RATIONAL SOLUTION.

*Rainfall data.*  
*Typical precipitation curves.*  
*Designing the sewers.*  
*Numbering of sewers.*  
*Essentials of the method outlined.*  
*Points which commend the above method.*

#### ACTUAL CONSTRUCTION AND RESULTS TO BE EXPECTED.

*Materials of construction.*  
*Contracts and specifications.*  
*Inspection.*  
*Maintenance.*  
*Degree of accuracy.*

### LIST OF TABLES.

Table	I.	Field covered by hydraulic engineering.
Table	II.	Excessive precipitations, giving rates per hour.

\*This paper embodies largely the results of a study of the question at Kansas City and is wholly devoted to storm water drains.

Table III.	Heavy precipitations by 40 min. time periods.
Table IV.	Heavy precipitations by 20 min. time periods.
Table V.	Heavy precipitations by 10 min. time periods.
Table VI.	List of U. S. weather bureaus, with weights used.
Table VII.	Precipitations used in determining form of 40 min. typical rain curve.
Table VIII.	Precipitations arranged symmetrically.
Table IX.	Method of obtaining typical intensities.

#### DRAWINGS ILLUSTRATING THE TEXT.

- Fig. 1. Map of U. S. Gauging stations.
- Fig. 2. Precipitation curve, Columbia, Mo.
- Fig. 3. Curves of perviousness.
- Fig. 4. Cumulative method of combining discharges.
- Fig. 5. Resultant curve for 40 min. period.
- Fig. 6. Plan of main sewers, Kansas City, Mo.

#### GENERAL FEATURES OF THE PROBLEM.

*Hydraulic Engineering and the City Water Problem.*—Broadly speaking, hydraulic engineering is the art and science of confining water. This confining is always relative rather than absolute, being an approximation toward making an unstable element stable. The city water problem consists in supplying and removing municipal water, its relative position in the hydraulic field being shown diagrammatically in Table I, under Sanitary.

During recent years great advance has been made in the conduct of this branch of municipal affairs. Most cities now have water departments, and not a few have well-organized sewer departments. The writer believes the time not far distant when these two departments will be more widely recognized as the complements of each other, and in the more progressive communities be placed permanently in charge of trained technical men of experience and ability.

Under competent business management, such a department would be in position to benefit most largely from the advice and experience of consulting engineers, and especially would it be possible to plan definitely as to the probable future needs of a city, and then proceed with reasonable assurance of actualizing such plans.

*The City Water Problem and Storm Drains.*—To most people, among whom may be included a large number of engineers, the sewerage problem means simply taking care of sanitary sewage, not appreciating the fact that some 99% of the flow in sewers would be foreign matter if viewed in this light. The realization that this view comprehends but half the problem has given rise to the economic demand for storm drains, which, though necessarily larger than sanitary sewers, can usually be correspondingly shorter, since natural drainage may be largely utilized.

*A Three-Fold View of the Question.*—Sanitary engineering deserves consideration from three points of view: the public, the taxpayer, and the engineer.

The public itself has a two-fold interest: to prevent a nuisance and to promote health in the community. The former is the more potent incentive to action, but the latter of more vital importance; and while the danger to health from this menace has been greatly overrated, it has been even more greatly ignored. At present many of the illusions regarding disease from so-called sewer gas have been dispelled, and at the same time a thoroughly active and normal interest has been aroused regarding the need for sanitary conditions.

The taxpayer looks upon sewers and sewage disposal works as necessary evils, the construction of which is to be postponed as long as possible and then accomplished with the smallest possible outlay of cash, regardless generally of kind or quality, or of the future needs of the city. In the role of taxpayers, people are naturally obstructionists, but this point of view is largely lost sight of where the work is carried on by means of bonds or the expense is defrayed from the general treasury; therefore, when feasible, one of these methods will be found advantageous.

The city engineer too often looks upon the subject as though it were divided into three parts; house drains and fixtures to be left in the hands of plumbers and inspectors, catch basins and the like to be constructed from standard plans on file in his office, large sewers and disposal works to be constructed after consultation with a specialist. The fact is that the specialist should be consulted regarding the entire system, otherwise how can the different parts form a complete whole? The natural desire of the engineer is to eliminate the first two points of view, substituting his judgment instead. It is well to bear in mind, however, that they have to be reckoned with, for the possibility of planning and completing a satisfactory system depends almost entirely on their relative ascendancy and influence.

*Essentials of a Good System.*—Until recent years, and still very largely, sewer systems were constructed haphazard and piecemeal, resulting in inefficiency and unnecessary cost. This can be obviated only by having a comprehensive plan to serve as guide in the design and construction of all sewers.

This plan should not only be comprehensive, but should be worked out in detail to a far greater degree than is generally assumed. By the very nature of things it will be many years in building, and, in fact, will never be entirely finished. This emphasizes the need for an early and rational determination of as many factors as possible, in order to best care for the present and future generations. No system would be considered modern which did not accommodate every building lot for sanitary purposes and supplement all gutters for storm runoff. This does not mean that

storm drains should run to summits like sanitary sewers; on the contrary, it is usually advisable to allow storm water to flow in the gutters for an entire block or more. The first street inlet, and consequent beginning of the sewer, should be placed as far from the summit as can be done without allowing the depth of water in the gutter to become a nuisance during heavy rains. This results in a considerable saving of money and is in accord with the accepted principle that storm drains are designed to supplement, not to replace gutters.

Another requisite is that sewers generally, should be constructed water-tight. If it were not for glaring defects of this nature in nearly every city of the land, such a statement would be considered self-evident. The need is especially urgent in sanitary sewers. On the other hand, if there were any great advantage in doing so, storm drains might be constructed with a view to allowing slight infiltration whenever the water table was above them, since at times when it was below there would be but slight objection if water did leak out, especially during the short period of a storm. This would enable them to act as drains in the true sense of the word, keeping the permanent water plane near the level of their invert. The chief objection to this is the additional depth and cost resulting from building them below the levels of cellars. The better way is to lay small drain tile for this purpose, directly below the storm drains, wherever local conditions require the draining of the land.

The question of allowable velocities is not well understood, in spite of the fact that engineers have had to deal with it for centuries. Economy in construction requires that velocities be limited by only two things—the general slope of the surface and possible erosion of the invert. The writer is of the opinion that danger to the latter has been greatly overrated, and is conducting a series of studies at the present time with regard to maximum limits of velocity in hydraulic work. The probability is that 20 ft. per sec. over a good concrete surface is perfectly feasible. With good concrete construction there is very little danger of the invert cutting out. On the other hand, the velocity must not be so low that the cost of attendance, in the way of cleaning and flushing, is unwarrantably high. In the case of flat and low-lying territory, like New Orleans for example, this is sometimes overcome by occasional pumping stations. Present opinion favors a minimum velocity of 20 in. per sec. during the lowest stages of sanitary sewers. A rule adopted by the writer is to allow 3 ft. per sec. when the sewer is half full, which accomplishes practically the same result and is readily applied when using tables or diagrams.

Every one recognizes that capacity is a vital consideration; but while it is of prime importance that sewers be adequate for present needs and future growth, it is not so generally recognized that if they are made unnecessarily large they will be less satis-

factory owing to low velocities and high cost of maintenance. This is especially true during the period of years elapsing while the territory served is being built up and paved. It is seldom feasible, as is so often done in the case of water supply mains, to supplement sewers by constructing parallel ones some years later. For this reason it is evident that the planning of a system to remove the water from a municipality becomes urgent much earlier than comprehensive plans for its supply.

Another essential is that the system be designed so as to minimize hand labor, cleaning the sewers as largely as possible by means of flushing with water. It is very desirable also that the flushing be by means of automatic flush tanks discharging at regular intervals, special occasions only being taken care of by using the hose. The cost of inefficient day labor in cleaning sewers is much greater than a large amount of water, even when purchased at high rates from a private company.

As a final thought, there are two tests which may be applied in forming a judgment concerning a sewer system: that it shall promote public health and prevent a nuisance, and that the first cost shall be as low as consistent with minimum maintenance charges.

*Disposing of Sewage.*—It is usually held as a desideratum that disposal works be located to one side and at some distance from a city,—the farther the better. This last is true provided the added cost of construction and maintenance be balanced against any possible nuisance which may be caused in the proximity of the works, with consequent deterioration of property values. It by no means follows that all of the sewage should be disposed of at one point, or even by the same method and to the same extent.

A popular misconception is that the proper disposition of sewage presupposes extensive and elaborate appliances; the fact being that it varies all the way from merely an outfall sewer into a stream of water requiring no attention whatever, to a complicated system of settling basins, septic tanks, filters and sludge disposal appliances, requiring a considerable force of skilled and common labor under the direction of scientific experts. The prime requisites are that it be efficient, simple, and economical.

*The Separate or Combined System.*—After careful study has been made of the available methods of sewage disposal, it is then possible to logically consider the relative merits of the separate and the combined systems. This is seldom a problem as such, usually resolving itself into supplementing a combined system in the older parts of the city, and in the newer and unsewered portions using the one or the other, depending on local conditions, or frequently a judicious combination of the two.

In addition to meeting natural conditions, these conclusions must largely satisfy the public point of view, or rather one's judgment as to what that view is and is likely to become; and then comparing cost estimates of various tentative plans until a system is

developed which may be built at as low a figure as is compatible with permanency and adequateness.

*Estimating the Amount of Sewage.*—To the lay mind, sewage is sewage wherever found; yet the composition of sewage in America is noticeably unlike that of Europe, a marked difference appearing even in the cities of this country. This difference comes largely in the amount of dilution and in the relative proportions of sanitary sewage, trade wastes, and storm water runoff. Only the latter will be considered in this paper.

The amount of storm water for which allowance should be made is generally determined by the application of some one of the well-known formulas, such as the McMath, Hering, Burtli-Ziegler, Parmley, Gregory, and others. A very elaborate determination has lately been made by Mr. C. E. Grunsky, member of the American Society of Civil Engineers, in his studies regarding "The Sewer System of San Francisco and a Solution of the Storm Water Flow Problem". One much easier of application, although not comparable in its analytic grasp of the subject, has been proposed by Mr. Carl H. Nordell, Bureau of Sewers, Borough of Queens, New York City. A method having somewhat similar features, and comprehensive in its treatment, has been developed by the writer and is being applied in the work at Kansas City.

Whatever method is followed, it is necessary to assume some maximum precipitation for which the system will be designed. Then, from local conditions, estimate the runoff to be cared for by the different sewers.

#### NECESSARY ASSUMPTIONS AND APPROXIMATIONS.

*Typical Sewer Lengths.*—By sewer length, in this connection, is meant the time required for water to flow through it, not its length in feet. Deciding upon typical lengths is a matter of judgment for each city, sometimes requiring to be changed in different portions of the same city.

Where the grades are fairly steep, as in Pittsburg, Kansas City, and other places similarly situated, time intervals for main, branch, and lateral sewers may be tentatively assumed at 40, 20, and 10 minutes respectively. In Chicago, New Orleans, and other cities having practically level streets, the periods may easily be 60, 30, and 15 minutes, or in extreme cases 2 hours, 1 hour, and  $\frac{1}{2}$  hour, unless there were outlets like the Chicago River, Lake Michigan, and Lake Pontchartrain, making the sewers very short. These cases are merely suggestive, and each city must be considered on its merits; in some cases two typical lengths will suffice, while in others four may be required. These time periods depend on both the absolute and relative length of the different sewers, as well as on the general shape of a city's typical rain curves.

A rigidly rational method would consider each sewer as an entity, treating it as though it were the only storm drain in the

city. This would mean determining the time of surface concentration, the perviousness of the surface, the frequency with which it would be permissible to flood it, a precipitation curve suited to its individual characteristics, and by means of trial solutions its actual time length; all of which would be manifestly impossible with the funds available for such work. There is grave question whether the present state of our knowledge would warrant such elaborate treatment, even if taxpayers were willing to pay for it.

On the other hand, a number of engineers have developed formulas with the hope of obviating many of the above difficulties. It is now quite generally admitted that no arrangement of coefficients is possible, which shall take into account all of the varying conditions and at the same time be sufficiently simple in its application; at least, that such efforts can be only a partial success until much more data have been secured from which deductions may be made.

There would seem to be room, however, for rational effort somewhere between these two extremes of treating a city's sewers as though they were all different or else all alike, and it is this middle ground which the writer has attempted to occupy. To lessen the work which would necessarily result if each sewer were treated independently, typical sewer lengths have been adopted; and to make certain of developing really typical rain curves, the question has been met squarely by deciding on definite surcharge periods, thus setting time limits when a city can better afford to have a sewer flooded than to pay for a larger one.

As an illustration of this point, so that we will see the drift of the next topic—Surcharge Periods—I asked Mr. John B. Hanna, Engineer of the Terminal Railway (which comprises the terminals of all the railroads entering Kansas City), as to how often they could afford to have their new station flooded. The question came very close home to them, since they are paying for the sewer in return for land reclaimed by closing up the creek. If the sewer is made large it costs more money, whereas if it is made small their yards and stations will be flooded more frequently. He said, "In my opinion we can say about ten years. We can not afford to have it flooded oftener than every ten years." You remember they had their old station flooded and all the baggage floated away by the Missouri River back in 1906, and the experience is fresh in their minds. With a sewer that will carry about 100,000 gallons every second a little change in the size of it means a good deal of money. This shows that the best way to arrive at the maximum rain which we wish to use in designing is to decide how often we can afford to have the sewers flooded rather than build them larger.

*Surcharge Periods.*—It is readily conceded that most cities cannot afford to build storm drains to care for their heaviest precipitations. If this were attempted, Columbus, Ohio, would build

for about 4 inches of rainfall, St. Louis and Milwaukee each for 5 inches, while Kansas City has experienced a rate of over 7 inches per hour, the average for 40 minutes being nearly 6 inches. As averages for 10, 20, and 40 minutes, the rates given in Table II were reached during the past 10 years by the cities mentioned.

It is worth noting in the table that if one were designing for the Shreveport rains there would probably be no need for typical sewer lengths, as its intensity varied less than 5%, whether considered for a period of 10 or of 40 minutes duration. Those at Kansas City and Topeka come next with a variation of about 15%, while the one at St. Louis varies nearly 40%.

Whatever method is used in computing the required carrying capacity of the sewers, it is necessary either directly or indirectly to decide how frequently a city can afford to have its storm drains flooded rather than to build them larger, and by so doing further increase its burden of debt and expenditure. This is a matter requiring greater judgment than any other confronting the engineer engaged in storm drain design.

As a question of economics, it resolves itself into the total loss caused by flooding streets and cellars to a greater or less extent, set over against the interest on such additional expenditure as would have prevented the flooding. In this connection it is well to remember that the loss considered must cover both the damage to property and the inconvenience which results.

As just indicated, the most careful thought should be given this phase of the subject. Each city will necessarily work out its own surcharge periods, depending on the shape of its rain curves, its financial ability, and the attitude of the people toward mortgaging the future.

In Kansas City it has been decided to design main sewers with the expectation of flooding every 10 years, branch sewers every 5 years, and laterals every 2 years. At first thought this seems too frequent in the case of laterals, but when it is borne in mind that they must be designed for 10 minute precipitations, and so must be much larger proportionally than either branch or main sewers, and that flooding in their case means simply carrying the water somewhat further in the gutters, it is readily perceived that true economy is served by making the time interval short.

*Permeability of Surface.*—It is now universally conceded that the perviousness of areas is only second in importance to the rate of precipitation, as a controlling factor in storm water runoff; since the runoff equals the precipitation less the perviousness.

The writer believes it preferable to estimate perviousness as depth in inches per hour which a given surface will absorb, rather than a given percentage of the rainfall, since there is little difference in the rate of absorption whether the rainfall be light or heavy, so long as the intensity of the downpour equals or exceeds the rate at which the surface is capable of absorbing it.

Perviousness depends on the kind and depth both of the surface soil and the sub-soil, and whether the surface is barren, covered with grass, or paved. Paved areas are usually considered impervious, but are only relatively so. This is demonstrated by the fact that the runoff from so-called impervious areas never equals the total precipitation.

In all probability the curve of perviousness is never a straight line; however, as a working basis, to be corrected later by the results of gaging, it has been assumed in Kansas City that paved surfaces absorb water at the rate of 0.50 in. per hour at the beginning of a storm, decreasing to 0.25 at the end of 15 minutes, and to 0.00 at the end of 60 minutes; that lawns and other grass surfaces absorb 0.75 in. at the beginning, decreasing to 0.50 at the end of 30 minutes, and to 0.00 at the end of 120 minutes; that garden and other barren soils absorb 1.00 in. at the beginning, decreasing to 0.75 at the end of 30 minutes, and to 0.00 at the expiration of 120 minutes. This is shown graphically in Fig. 3.

*Surface Concentration.*—The time required for surface concentration depends on the distance to catch basins and the mean slope of the surface. In calculations involving this time, the velocity of flow at Kansas City was assumed, from the meager data available, to be 100 ft. per min. for an unpaved surface having a slope of 5 ft. to the hundred; other slopes being in proportion. Paved surfaces were assumed at twice the velocity.

The type of runoff tract used is 330 x 660 ft., being a standard city block. With this as a basis, three typical areas were worked out as follows: Type I, having 20% of paved surface and two-thirds of the remainder barren. Type II, 50% paved and equal portions of barren and lawn surface. Type III, 80% paved and one-third of the remainder barren.

These are proving satisfactory for study purposes and tentative designs. They give one, two, and three blocks as the respective distances which require 5 minutes, where the slope is 5%.

#### A RATIONAL SOLUTION.

*Rainfall Data.*—There can be no doubt that more grave errors in storm drain design have been due to lack of reliable and complete information than to all other causes combined. This realization led the writer, during the preliminary studies in Kansas City, to devote much time and thought to gathering and compiling exhaustive rainfall data.

Since automatic records have been kept for but little more than a decade, the records from a single city are insufficient for reliable work, so data have been gathered and tabulated from the entire watershed of the Mississippi River, as shown in Fig. 1. All weather bureaus having automatic records extending over a period of 5 years or more have contributed their heavier precipitations, and the information here presented is believed to be both reliable and complete.

A careful study of the question has led the writer to conclude that for ranking rains in the order of their intensities, the method of average precipitation is at once simple and adequate, therefore satisfactory. This method has been used in preparing the following tables. They were computed for the 40, 20, and 10 minute periods by the use of the planimeter, as illustrated in Fig. 2, the areas being taken between the vertical lines, which are equal maximum ordinates enclosing the given time intervals.

The first step, then, after the records are gathered and plotted, is to determine the average intensity of each rain for the different time intervals. It should not be lost sight of that these averages in no wise enter into the computations of sewer discharge, but are

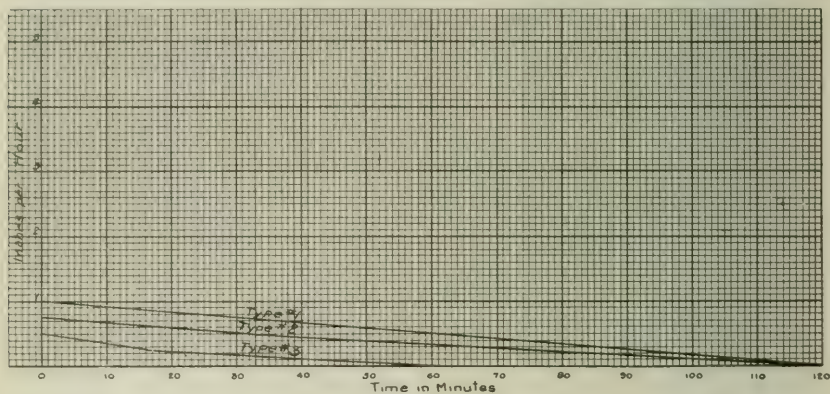


FIG. 3 CURVES OF PERVIOUSNESS

used merely in the arrangement of the tables. Tables III, IV, and V contain the data so arranged.

*Typical Precipitation Curves.*—The matter of greatest importance in planning and designing a storm sewer system is the determination of typical precipitation curves. The exercise of judgment comes mainly in the selection of surcharge periods, the following work being largely a question of mathematics.

It is essential that the rainfall data be from automatic gages which record the depth in inches falling each five minutes. This makes it possible to plot curves showing both the total and rate of precipitation, the usual way being to use time as abscissas and rates per hour as ordinates.

It is unnecessary to plot the records of all rains, as much time and labor can be saved by setting a minimum limit below which rains will be omitted. The choice of this in no way affects the validity of the method or the correctness of the results secured. For the Mississippi Valley, and the Middle West generally, very satisfactory limits are as follows: a precipitation of 0.25 in. during

some five minutes of the storm and a total precipitation of at least an inch of rainfall.

In order to present clearly the method of computing a typical rain curve, a simple illustration will be used. Suppose a city has ten rains in ten years; it is clear that the hardest one occurred once in the ten years; that one equal to or exceeding the next hardest occurred every five years, for it and the hardest both occurred during the ten years, or an average of every five years

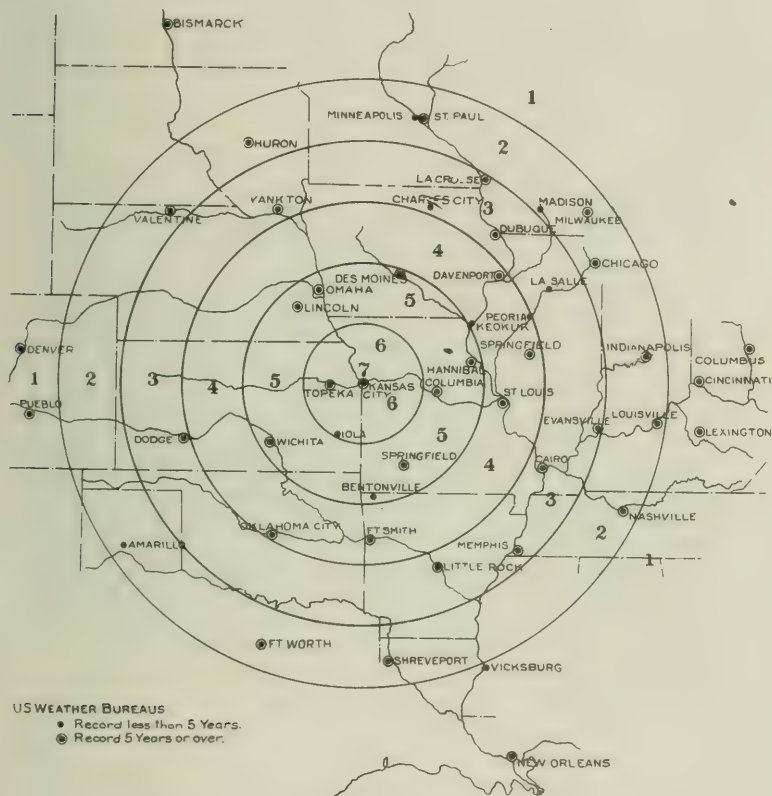


Fig. 1. Map Showing U. S. Gauging Stations.

for the one or the other. The same line of reasoning shows that one equal to or exceeding the fifth hardest occurred every two years.

The method is still logical no matter how many rains occurred, and if the ten hardest are used, being as many as the number of years considered, it determines what rains may be expected to flood the sewers for any surcharge periods selected.

Since data are used from different gaging stations, it becomes necessary to reduce their records to a common basis. Probably 10 is the most convenient one to use, so this will be employed throughout the discussion. If the record has been kept for more than 10 years, say 11 for example, each rain must be weighted by  $10/11$ , using the actual intensity, but taking 11 instead of 10 rains into account. Likewise, if the record is available for only 6 years, each rain must be weighted by  $10/6$ . It is hardly necessary to mention that the longer the record the more satisfactory its use, since interpolating is always preferable to extrapolating. If some number other than 10 years had been selected as standard, the numerator of the above fractions would correspond.

Another point needs to be considered at this time; all

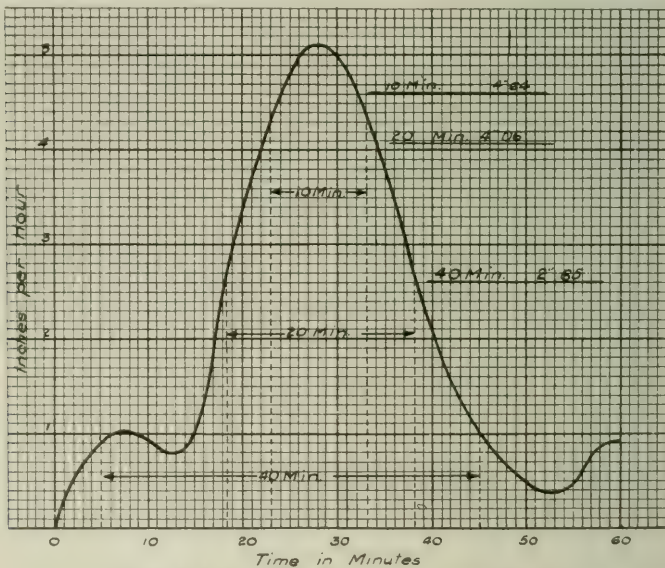


FIG. 2 - PRECIPITATION CURVE. COLUMBIA, MO.

engineers will agree that cities situated in the same drainage basin may be expected to show rain curves somewhat similar in form and intensity, so that the records of all such cities may properly be considered in estimating future probabilities; they will likewise agree that a city's own rains will be a truer index of what may be expected in the future than the precipitations at other places several hundred miles distant. For this reason, the records have been weighted, giving Kansas City a weight of 7, cities within 100 miles 6, 200 miles 5, and so on, until those at a distance greater than 500 miles, but still within the Mississippi Valley, are given a weight of 1.

Table VI gives the final weights of the different cities, and the method of their computation. These have been obtained as follows: the number of years for which rains are considered is divided by the length of time the record is available, and this quotient is multiplied by the distance weight of the city. For Topeka, Kansas, this gives

$$10 \div 8\frac{1}{2} \times 6 = 7.$$

With surcharge periods of 10, 5, and 2 years already determined upon, the *Total final weight* is multiplied by 1, 2, and 5 (obtained by dividing 10 by 10, 5, and 2) as given at the bottom of Table VI. This gives partial totals of 149 to be used with Table III, 298 with Table IV, and 745 with Table V. Opposite these in the tables we find 2.62, 3.26, and 3.42, which are the average intensities of the three typical precipitation curves.

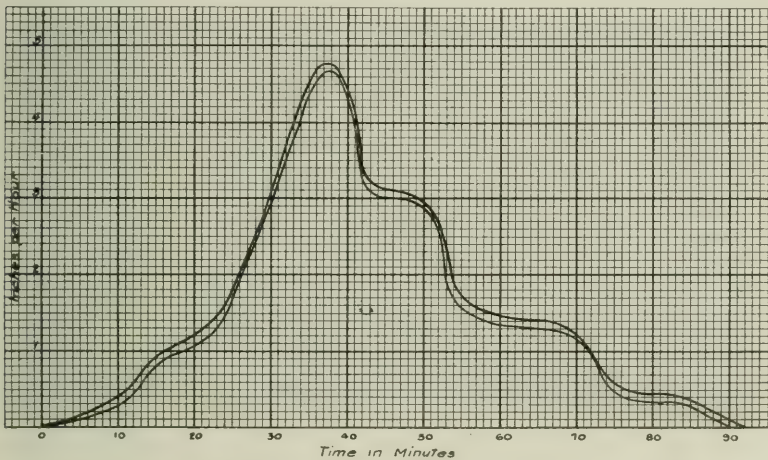


FIG. 5 - RESULTANT CURVE FOR 40 MIN. PERIOD

It now remains to determine the form of each of these curves. The 40 minute curve will be used to illustrate the operation. This is best seen by reference to Table IX, where it will be noticed that ten weights above and ten below have been used. Either more or less rains might have been used, depending on the judgment of the engineer as to how many are required to derive a curve which shall be truly typical in shape. Since the intensity for the period is in no wise affected, a comparatively large error in judgment results in but slight error in design, thus reducing the personal equation to a minimum.

Table VII gives the rains thus selected. The amount of precipitation for each 5 minutes is given, with the beginnings of the rains directly under each other. In Table VIII, these are arranged symmetrically with regard to their maximum inten-

sities, since this arrangement is best adapted to obtaining a curve which shall most nearly represent them in its form characteristics.

In Table IX the same arrangement is preserved, but the different values are multiplied by the respective weights of the rains taken from Table III. The columns are then added and the sums divided by 20, since a total of twenty weights was used. In order to obtain ordinate values for plotting, these quotients are multiplied by 12 so as to get rates per hour. These rates are given in the last line, the curve being shown by the lighter line of Fig. 5. This gives the correct form of the typical precipitation curve desired, but not necessarily its magnitude, which may be either more or less. In the present instance the curve has to be increased slightly in intensity, this being done so as to make the rate for 40 minutes 2.62 in. per hour, as given in the table. The final curve is shown by the heavier line in the figure.

As previously suggested, the method contemplates the use of a precipitation curve for each typical sewer length, varying in number probably from one to four in different cities. To make the need for this apparent, suppose the rain curve for 40 minute sewers were used for 20 and 10 minute sewers, it would in effect greatly reduce their surcharge periods.

Taking the rain immediately above 2.62, which is the average intensity for 40 minute sewers, the *Partial Totals* in the different tables are found to be 149, 796, and 1241. Dividing each of these by 149 gives 1, 5.35, and 8.33; then dividing 10 by each of these gives 10, 1.86, and 1.20. In other words, the 40 minute sewer would be flooded every ten years (which had been assumed), the 20 minute sewer a little oftener than every two years and the 10 minute sewer a little more frequently than once every fifteen months.

Or take the illustration the other way; suppose the rain curve for 10 minute sewers were used for 40 and 20 minute drains, it would have the effect of increasing their surcharge periods. The average intensity would then be 3.42, opposite 35, 229, and 745 in the columns of partial totals. Dividing as before gives final quotients of 42.6, 6.5, and 2; which means that the different classes of sewers would be flooded about every 40, 6, and 2 years respectively.

The tables can readily be used to determine the surcharge periods for any desired intensity of rain. If a precipitation can be found which will give satisfactory surcharge periods for the different classes of sewers, it would in effect reduce them to one. This is the ideal condition, but should not be expected to occur often in practice.

*Designing the Sewers.*—With the time length of a sewer approximated and the typical rain determined, it is then only

necessary to decide from this rain curve the amount of runoff which will reach the sewer from each runoff tract, and use this in conjunction with the grade that can be secured. With these data in hand, the size of sewer and velocity of flow are readily computed.

Referring to Fig. 4, it illustrates how the runoff from the different tracts is combined so as to obtain a cumulative effect comparable with actual conditions. It will be noticed that the calculations are all graphical, this method being simple, rapid, and of sufficient accuracy. The different values might be added, but the work would be laborious and there would be greater danger of errors creeping in. By repeating this process wherever

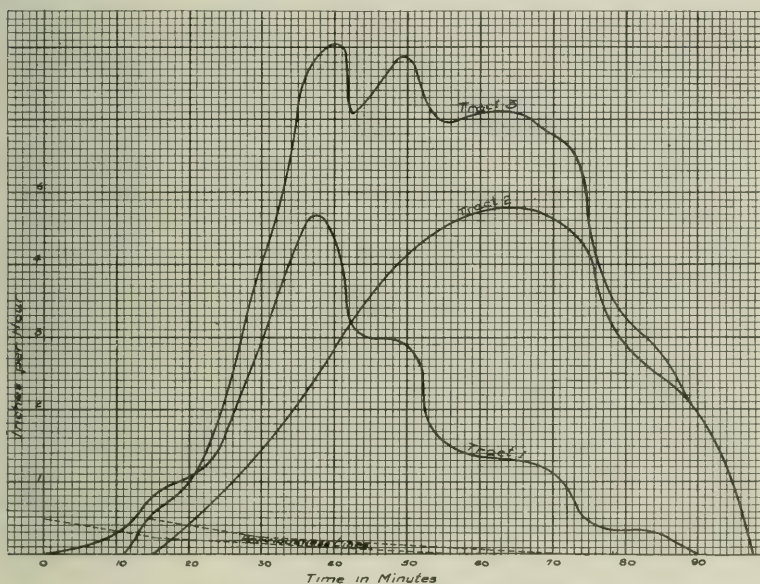


FIG. 4 - CUMULATIVE METHOD OF COMBINING DISCHARGES

more water enters the sewer, the required size is synthetically built up.

With the velocity of flow determined, the time is computed which will be required for the water to flow from the first catch basin to the second, or to where another sewer joins it, the writer's practice being to compute time lengths for periods of five minutes or over, using the nearest five minutes in adjusting the curves. Whenever our knowledge of surface concentration shall have become sufficiently definite, it will be advisable to work to minute intervals instead of only to five minutes.

A curve is then drawn which in magnitude equals the typical curve multiplied by the area drained, for each of the runoff tracts,

the second one being moved toward the right as many minutes as the time required for the water to flow from the first point to the second. This is shown in the figure by *Tract 1* and *Tract 2*. The two curves are then combined by making a new one with ordinates equal to the sum of their ordinates above the lines of *Perviousness*. This new curve represents the flow below the junction point.

When the outlet is reached, the shape and magnitude of the last curve gives a correct graphical representation of the resulting flow to be expected at this point. At first glance it would seem that much time would be consumed. On the contrary, it is surprising how rapidly and certainly results can be obtained.

To design a sewer for any part of the city, always begin with the laterals and work toward the branches and from that to the main sewers. In other words, follow with the computations the order followed by the water in filling sewers. Whenever advisable the method may be combined with the use of any of the formulas already mentioned.

*Numbering Sewers.*—If some simple and yet rational system of numbering sewer districts be adopted, it not only saves a great deal of inconvenience but much lost time and frequent errors. This may be illustrated by the method proposed for Kansas City. By charter the entire territory within the corporate limits is divided into sewer divisions and these into sewer districts. For purposes of designing, the divisions are subdivided into drainage areas, these into runoff tracts, and these again into sewer districts. See Fig. 6.

Including the new territory, eight divisions are being proposed for the city. These are being divided into drainage areas, not to exceed nine for each division; these again into runoff tracts, not to exceed nine for each area; the tracts being divided in the same way into sewer districts, the highest possible number being 8999. As a matter of convenience, the numbers follow up the sewers. This can best be illustrated by an example.

Sewer district number 5439 means that it is located in division 5, drainage area 4 of this division, runoff tract 3 of this area, and sewer district number 9 in this tract. It also shows that the property embraced within its limits is located near the center of the city, otherwise it would not be in division 5; that it is near the middle of that division, being area No. 4; that it is in the lower part of the area and the highest part of the tract, as indicated by the figures 3 and 9.

It is not only of great advantage in at once locating a sewer, since the sewer has the same number as the district which it serves, but is of equal importance while designing, since each sewer flows into one of a lower number, thus avoiding occasion for mistakes and so insuring accuracy and rapidity in the work.

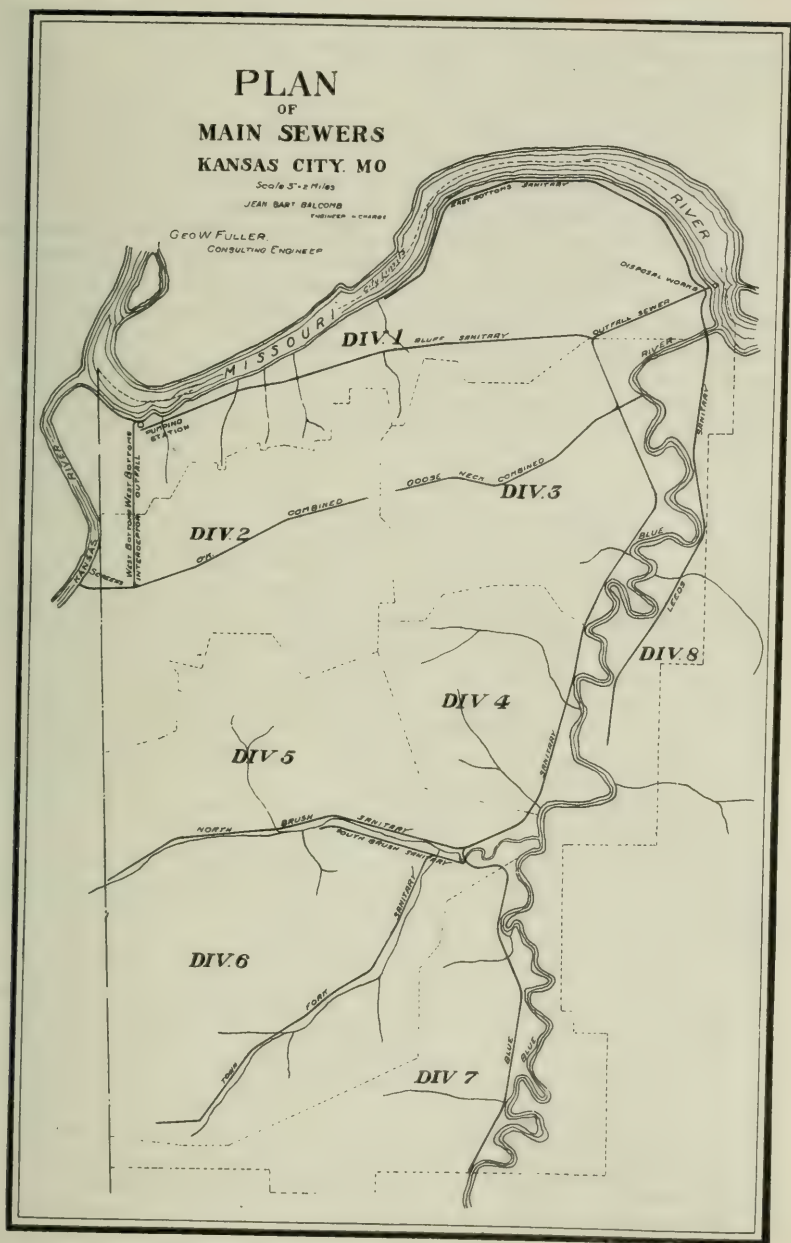


Fig. 6. Plan of Main Sewers—Kansas City, Mo.

December, 1910

*Essentials of the Method Outlined.*—The emphasis in the method proposed above is placed on the following points:

Surcharge periods.

Typical sewer lengths.

A typical rain curve for each sewer type.

Method of deducing these curves.

Method of estimating perviousness.

Cumulative method of sewer computation.

Most of the earlier attempts to solve the storm flow problem considered these same features, although frequently not with such explicitness, as the requirements were not then so well understood. Aside from the method of estimating the perviousness, only brief consideration is given to the subjects of permeability and time of surface concentration, since these phases of the question still wait on the gathering of more data, so that something approaching complete and reliable information may be at hand.

*Points Which Commend the Above Method.*—It follows nature in being cumulative in results obtained.

It is a combined analytic and synthetic method.

The direction of storms can readily be allowed for.

It is adapted to any degree of refinement.

There is no uncertainty as to where maximum periods occur.

It can be used to solve the problem independently, or in conjunction with any other method.

Wherever it is necessary to exercise judgment, the conditions to be met are definite and certain.

No averages are used in computing capacities, the actual rain variations being followed.

There are no coefficients to be approximated, with consequent probability of large and uncertain errors.

It does not depend on formulas or difficult mathematical determinations, yet secures results agreeing with the facts up to the limits of the data available.

#### ACTUAL CONSTRUCTION AND RESULTS TO BE EXPECTED.

*Materials of Construction.*—The decision as to what materials to use in construction has been controlled largely in the past, and still is to some extent, by the materials manufactured or for sale by local firms, through political affiliations, and social friendships. This is being greatly lessened owing to a closer study of the subject by municipal hydraulic engineers, and a large interest and better understanding by the general public of the needs and requirements of a thoroughly up-to-date sewerage system.

It may be a matter of surprise to some that rectangular wooden sewers have been built in a number of instances and have given excellent service through a term of years, but finally becoming at least indirectly a public nuisance. It is not to be

supposed that any engineer would recommend such construction today, as the defects of wood for this purpose are now well recognized.

For large sewers, brick was well-nigh universally used until concrete was found to be a much better material. The use of brick is growing less and less, owing to the large number of joints and the lack of tensile strength in the completed structure. This is emphatically true unless the sewers are lined with cement mortar. A special invert is also required as many serious cases of erosion are on record. The chief reasons for using brick were its cheapness, its availability, the supply of suitable skilled labor, and the ease with which vitrified brick or Belgian blocks could be laid in the invert, after this was found necessary in order to avoid their cutting out where even moderate velocities were used.

For small sewers, it is generally agreed that vitrified pipe, with bell and spigot joint well caulked and then filled with portland cement mortar, is the best material at hand. At the same time it is fully recognized that such frequent joints make it an undesirable material, partly because it is almost impossible to inspect each individual joint in its entirety, and partly because it is, to say the least, very inconvenient to do good work and make the joints water tight. When laid on steep slopes, the joints, being of a material foreign to the pipe and adhering only fairly well, make natural places for erosion to begin. This frequently continues until water finds its way in or out of the sewer, depending on the level of the water table at different seasons of the year.

The present consensus of engineering opinion favors the use of concrete, generally reinforced, and either monolithic or in the form of pipe, for nearly all sewers larger than 30 inches inside diameter. Sewers 24 inches to 30 inches are still debatable ground. Concrete pipe with longitudinal bar reinforcement possesses many of the characteristics which must obtain in the sewer construction material of the future. It is to be hoped that a substitute for vitrified pipe may be found, or that a better joint may be devised, or else that it may be found feasible to construct small sizes of concrete pipe with an entirely satisfactory method of joining them.

*Contracts and Specifications.*—Much good work has been done along this line in the past few years, and yet the present forms of contract and specifications are far from satisfactory. In a letter to *Engineering-Contracting*, published February 10, 1909, the writer made the following statement, which has not thus far been questioned, and which he wishes to reiterate in the present instance:

“In order to draw up an equitable contract, or judge of one that is drawn, the first requisite is that it shall be fair to

both parties, assuming them both to be honest and actuated by right motives. The second is to have it formulated so there is no motive for dishonesty by either party—so that whether an honest or dishonest course is followed it will result in a gain or loss to both parties, never a gain to one and a loss to the other.”

Of the various modifications and forms proposed, the one which seems to be entirely adequate, and at the same time adapted to existing needs and conditions, may best be described as follows: Cost plus a fixed sum, with bonus and forfeit clause regarding both the time limit and the total expenditures; all extras to be paid for by cost plus a percentage.

*Inspection.*—With the old form of contract, it had become tacitly understood that laxity of inspection would counterbalance rigor of contract. The result has been that it often did far more than this. Whereas the specifications called for practically a perfect sewer, the actual construction fell unwarrantably below even reasonable requirements.

On the other hand, with the more reasonable forms of contract now coming into vogue, it is beginning to be possible to make the work of the inspector something more than a matter of form, and to really get sewers built very closely in accordance with the designs. The writer is firmly of the belief that a reasonable contract with honest inspection will correct many of the evils from which urban communities now suffer.

*Maintenance.*—The maintenance and repair of sewers, having been entirely removed from the engineering department in all of the larger cities, will be passed with a single thought.

While the day labor employed by cities is in many cases better than it formerly was, yet it is frequently untrustworthy and cannot be depended upon to carry out regulations regarding cleaning and flushing sewers. Also, it is notoriously inefficient. For the sake of economy, it is advisable to place automatic flush tanks at practically all dead ends, and to construct street inlets rather than catch basins, except where the latter are absolutely necessary, depending mainly on flushing to keep the sewers clean. It is also advisable, in sanitary sewers, to see that the building regulations require a vent from the soil pipe to the roof of each building, so that when sanitary sewage conveyed by the separate system has once passed the trap inside of the building, there shall be no other traps until it is finally discharged through the outfall sewer or at the disposal works.

*Degree of Accuracy.*—Engineers are prone to approach this problem as though it could be solved exactly. This is the desideratum, but it cannot be even closely approximated until much more experimental work has been done and a large amount of additional data has been gathered, so that judgments may be formed, rules formulated, and the practice standardized.

Engineers go to great lengths to determine the exact daily consumption per capita and the amounts of water used by manufacturing concerns, so as to know very closely the amount of house sewage and trade wastes; then very largely guess at the amount of seepage water, after which the figures are increased perhaps 50% to allow for periods of maximum flow; and then the sewer is designed, so that on the basis of these computations it will run two-thirds or three-fourths full during maximum flow.

In order to arrive at the amount of runoff, engineers make careful estimates of the perviousness of the surface, its general slope and the time of surface concentration; and then arbitrarily assume some depth of rain which may or may not closely approximate the maximum rainfall for that city, or some pre-determined amount less than this maximum.

This is all necessary, and the writer warmly endorses doing all such work as accurately as possible, laying stress on the refinement of details as rapidly as our knowledge warrants such action, but it should not be expected that absolutely correct results have been attained, after all this is done. Neither is it to be inferred that in this respect the hydraulic engineer is behind the structural, mechanical, or other engineers of the profession.

A sewer system should be designed for 25 years, for 50 years, for all time; and engineers accomplish this with a remarkably small margin of error. Yet no one would think of expecting an architect or structural engineer to build a factory so that it would handle a small output economically and at the same time be capable of caring for the unknown future growth of the business. If in the erection of a steel frame building or in the construction of a machine, where working conditions are pre-determined and the strength and properties of the steel may be found out completely in the laboratory and testing machine, it is deemed necessary to allow factors of safety from 3 to 20; hydraulic engineers are to be congratulated, since many of the conditions with which they deal are difficult and some of them practically impossible to determine, yet withal satisfactory results are achieved.

Table I. FIELD COVERED BY HYDRAULIC ENGINEERING.

Hydraulic Engineering	Agricultural	Drainage.
		Irrigation.
	Sanitary	Waterworks.
		Sewerage.
	Power	Water
		Electrical.
	Transportation	Harbor improvements.
		Ship canals.
		River improvement.

Table II. EXCESSIVE PRECIPITATIONS, GIVING RATES PER HOUR.

City.	Date.	Time Periods.		
		10 min.	20 min.	40 min.
Kansas City, Mo.....	8-23-06	6.78 in.	6.48 in.	5.79 in.
St. Louis, Mo.....	7-8-98	6.03 in.	4.92 in.	3.66 in.
Milwaukee, Wis.....	6-24-04	5.78 in.	4.64 in.	3.98 in.
Ft. Worth, Tex.....	9-21-00	4.90 in.	4.14 in.	3.70 in.
Cairo, Ill.....	6-28-05	4.74 in.	3.84 in.	3.32 in.
Columbus, Ohio.....	7-11-97	4.57 in.	4.11 in.	3.51 in.
Little Rock, Ark.....	7-11-03	4.42 in.	3.98 in.	3.36 in.
Topeka, Kans.....	8-2-03	4.02 in.	3.72 in.	3.48 in.
Shreveport, La.....	7-23-05	3.86 in.	3.74 in.	3.70 in.

Table III.  
HEAVY PRECIPITATIONS.  
40 MINUTES.

City.	Date.	Av. Rate		Final tial	Par- tial	City.	Date.	Av. Rate		Final tial	Par- tial
		per hr.	Wt.					per hr.	Wt.		
Kansas City, Mo..	8-23-06	5.79	7	7		Dodge City, Kans..	6-7-99	2.94	■	87	
Milwaukee, Wis...	6-24-04	3.98	2	■		Wichita, Kans.....	9-17-05	2.92	10	97	
Shreveport, La...	7-23-05	3.70	4	13		Louisville, Ky.....	8-8-93	2.90	2	99	
Ft. Worth, Tex....	9-21-00	3.70	3	16		New Orleans, La...	3-17-04	2.86	1	100	
St. Louis, Mo.....	7-8-98	3.66	4	20		Nashville, Tenn....	8-21-02	2.82	2	102	
Columbus, O.....	7-11-97	3.51	1	21		New Orleans, La...	7-19-01	2.81	1	103	
Topeka, Kans.....	8-02-03	3.48	7	28		New Orleans, La...	7-19-01	2.81	1	104	
Topeka, Kans.....	9-13-01	3.40	7	35		Columbia, Mo.....	8-25-00	2.78	5	109	
St. Paul, Minn...	8-9-02	3.36	2	37		Oklahoma City,					
Little Rock, Ark...	7-11-03	3.36	3	40		Okla. ....	6-4-04	2.78	■	113	
Cairo, Ill.....	6-28-05	3.32	3	43		Little Rock, Ark...	11-28-05	2.78	3	116	
Ft. Worth, Tex....	3-25-04	3.20	3	46		Kansas City, Mo...	9-14-05	2.77	7	123	
Columbia, Mo.....	5-31-02	3.20	5	51		Evansville, Ind....	8-14-06	2.74	4	127	
Little Rock, Ark...	5-8-00	3.14	3	54		Nashville, Tenn....	6-15-97	2.72	■	129	
Cairo, Ill.....	6-13-99	3.10	3	57		New Orleans, La...	7-11-04	2.71	1	130	
Ft. Worth, Tex....	6-3-04	3.10	3	60		Oklahoma City					
New Orleans, La...	8-25-04	3.09	1	61		Okla. ....	5-29-05	2.70	■	134	
Davenport, Ia.....	8-26-07	3.06	7	68		Des Moines, Ia....	7-14-07	2.67	5	139	
Omaha, Neb.....	7-6-98	3.03	5	73		Evansville, Ind....	9-2-00	2.66	4	143	
Columbus, O.....	6-23-01	3.02	1	74		Lexington, Ky....	8-22-00	2.65	1	144	
Wichita, Kans....	7-6-04	2.96	10	84		Columbia, Mo.....	8-22-05	2.65	5	149	

(149 weighted rains occur every 10 years.)

City.	Date.	Av. Rate		Final tial	Par- tial	City.	Date.	Av. Rate		Final tial	Par- tial
		per hr.	Wt.					per hr.	Wt.		
Shreveport, La....	6-1-06	2.62	4	153		Springfield, Mo...	7-19-06	2.44	10	224	
New Orleans, La...	3-14-03	2.60	1	154		Davenport, Ia.....	9-9-03	2.44	7	231	
Springfield, Mo...	7-26-05	2.58	10	164		Nashville, Tenn....	6-15-05	2.43	■	233	
Topeka, Kans.....	6-24-03	2.58	7	171		Ft. Worth, Tex....	5-2-06	2.40	■	236	
Little Rock, Ark...	5-21-98	2.56	3	174		Memphis, Tenn....	8-9-05	2.38	■	239	
Hannibal, Mo.....	5-26-06	2.54	5	179		Nashville, Tenn....	9-4-06	2.38	2	241	
Wichita, Kans.....	6-15-05	2.53	10	189		Nashville, Tenn....	6-9-03	2.38	2	248	
Nashville, Tenn...	9-1-00	2.53	2	191		New Orleans, La...	4-25-07	2.37	1	244	
New Orleans, La...	3-14-03	2.51	1	192		Columbia, Mo.....	5-25-03	2.37	5	249	
Little Rock, Ark...	9-15-98	2.50	3	195		Milwaukee, Wis...	9-17-07	2.36	3	251	
Milwaukee, Wis...	9-2-00	2.50	2	197		Lincoln, Neb.....	8-15-00	2.32	6	257	
Cincinnati, O.....	7-5-97	2.50	1	198		Dodge City, Kans...	8-18-04	2.32	3	260	
Dubuque, Ia.....	8-15-07	2.50	5	203		Kansas City, Mo...	9-9-03	2.32	7	267	
Shreveport, La...	6-27-02	2.47	■	207		Oklahoma City,					
Lincoln, Neb.....	5-10-05	2.45	6	213		Okla. ....	5-5-99	2.32	4	271	
New Orleans, La...	3-14-03	2.44	1	214		Dodge City, Kans...	7-19-97	2.32	3	274	

City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.	City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.
New Orleans, La.	8- 5-98	2.30	1	275	Oklahoma City				
Kansas City, Mo.	3-24-04	2.30	7	282	Okl.	8-28-00	1.87	4	543
Huron, S. D.	8- 8-04	2.30	2	284	Huron, S. D.	6-24-02	1.86	2	545
New Orleans, La.	7-11-06	2.29	1	285	Topeka, Kans.	9-22-02	1.85	7	552
Kansas City, Mo.	7-14-07	2.26	7	292	Louisville, Ky.	7-10-97	1.84	2	554
Dodge City, Kans.	7-21-07	2.26	3	295	Columbus, O.	7-19-00	1.84	1	555
Huron, S. D.	6-27-05	2.26	2	297	Nashville, Tenn.	7-11-97	1.84	2	557
La Crosse, Wis.	7- 9-03	2.26	5	302	Columbia, Mo.	10- 6-00	1.84	5	562
Columbia, Mo.	6-25-99	2.24	5	307	Lincoln, Neb.	8- 7-07	1.84	6	568
Shreveport, La.	4-11-05	2.24	4	311	Lincoln, Neb.	7-22-02	1.84	6	574
Yankton, S. D.	8-23-06	2.22	3	314	St. Paul, Minn.	9- 5-04	1.84	2	576
St. Louis, Mo.	8- 6-07	2.20	4	318	Kansas City, Mo.	9- 5-98	1.84	7	583
Little Rock, Ark.	6- 1-98	2.20	3	321	Davenport, Ia.	9-14-03	1.84	7	590
Hannibal, Mo.	8- 8-99	2.20	5	326	Des Moines, Ia.	4-22-97	1.83	5	595
Milwaukee, Wis.	8-23-98	2.20	2	328	Omaha, Neb.	6-26-06	1.82	5	600
Cincinnati, O.	7-22-06	2.19	1	329	New Orleans, La.	8-12-06	1.82	1	601
Dodge City, Kans.	6-17-06	2.18	3	332	Ft. Worth, Tex.	8-11-06	1.82	3	604
St. Paul, Minn.	7-30-04	2.16	2	334	Cincinnati, O.	8- 3-00	1.81	1	605
Wichita, Kans.	7-14-04	2.16	10	344	Chicago, Ill.	7-28-06	1.80	2	607
Evansville, Ind.	9- 2-04	2.16	4	348	St. Paul, Minn.	7-25-97	1.80	2	609
Columbia, Mo.	9-17-05	2.15	5	353	New Orleans, La.	6- 7-04	1.80	1	610
Shreveport, La.	5- 7-07	2.14	4	357	Topeka, Kans.	8- 4-06	1.80	7	617
Columbia, Mo.	6-14-98	2.12	5	362	Little Rock, Ark.	4-24-05	1.78	3	620
Indianapolis, Ind.	3-31-04	2.12	2	364	New Orleans, La.	6-20-00	1.78	1	621
Cairo, Ill.	6-22-97	2.11	8	367	Little Rock, Ark.	7-29-00	1.78	3	624
New Orleans, La.	5-23-07	2.10	1	368	Hannibal, Mo.	7- 7-98	1.76	5	629
St. Paul, Minn.	8-18-07	2.10	2	370	Huron, S. D.	8- 8-01	1.76	2	631
New Orleans, La.	4-17-01	2.08	1	371	Oklahoma City				
Ft. Smith, Ark.	6-30-07	2.08	7	378	Okl.	8- 7-06	1.76	4	635
Des Moines, Ia.	7-18-04	2.08	5	383	Omaha, Neb.	7-15-00	1.75	5	640
New Orleans, La.	9-16-01	2.06	1	384	Indianapolis, Ind.	6- 4-06	1.75	2	642
Oklahoma City					Columbia, Mo.	4-24-04	1.74	5	647
Okl.	5-23-03	2.06	4	388	Wichita, Kans.	6- 2-04	1.74	10	657
Yankton, S. D.	9-20-02	2.06	3	391	St. Louis, Mo.	7-29-03	1.73	4	661
Valentine, Neb.	7-21-04	2.06	3	394	Dodge City, Kans.	5-13-98	1.72	3	664
Kansas City, Mo.	8- 2-05	2.06	7	401	New Orleans, La.	3-19-05	1.72	1	665
Evansville, Ind.	7-20-04	2.06	4	405	Nashville, Tenn.	6-27-04	1.72	2	667
Dodge City, Kans.	7-23-99	2.06	3	408	Shreveport, La.	4- 2-05	1.72	4	671
Shreveport, La.	5- 3-06	2.05	4	412	Shreveport, La.	5-21-05	1.72	4	675
Valentine, Neb.	7- 9-07	2.04	3	415	Huron, S. D.	8-18-04	1.71	2	677
Memphis, Tenn.	7-16-06	2.04	8	418	Bismarck, N. D.	6-13-01	1.71	1	678
Cairo, Ill.	6- 7-00	2.04	3	421	Kansas City, Mo.	7- 7-02	1.71	7	685
St. Paul, Minn.	6-12-99	2.04	2	423	Columbus, O.	6-14-04	1.71	1	686
New Orleans, La.	7- 4-03	2.04	1	424	Shreveport, La.	7-23-02	1.70	4	690
Yankton, S. D.	7-15-00	2.04	3	427	Columbia, Mo.	7-18-02	1.68	5	695
Springfield, Mo.	6-24-06	2.03	10	437	Dodge City, Kans.	8- 6-03	1.68	3	698
Columbus, O.	7-28-02	2.02	1	438	Springfield, Mo.	8- 7-06	1.68	10	708
Dodge City, Kans.	8- 6-98	2.02	3	441	Ft. Worth, Tex.	5- 3-04	1.68	3	711
Columbia, Mo.	9-18-04	2.02	5	446	Cairo, Ill.	7-30-01	1.68	3	714
Kansas City, Mo.	5-23-02	2.02	7	453	Dubuque, Ia.	9-25-04	1.68	3	719
New Orleans, La.	7-15-01	2.01	1	454	Des Moines, Ia.	7-19-04	1.66	5	724
Wichita, Kans.	5-20-03	2.00	10	464	Little Rock, Ark.	8-25-99	1.66	3	727
Lincoln, Neb.	5-28-05	2.00	6	470	Indianapolis, Ind.	7- 6-04	1.65	2	729
Evansville, Ind.	5-30-00	2.00	4	474	New Orleans, La.	9- 9-98	1.65	1	730
La Crosse, Wis.	8- 4-05	1.98	5	479	Oklahoma City				
Yankton, S. D.	7-14-00	1.96	3	482	Okl.	8-12-01	1.64	4	734
Memphis, Tenn.	11-19-06	1.96	3	485	Springfield, Mo.	6- 4-04	1.64	10	744
Nashville, Tenn.	6- 7-00	1.95	2	487	Lexington, Ky.	7-19-02	1.63	1	745
Hannibal, Mo.	6- 4-04	1.95	5	492	Des Moines, Ia.	7-19-05	1.62	5	750
Lincoln, Neb.	7-15-00	1.95	6	498	Memphis, Tenn.	8-18-01	1.62	3	753
Ft. Worth, Tex.	6-24-03	1.94	3	501	St. Paul, Minn.	8- 5-98	1.62	2	755
Valentine, Neb.	6-27-05	1.94	3	504	Nashville, Tenn.	9-14-01	1.61	2	757
Indianapolis, Ind.	8- 2-99	1.93	2	506	Oklahoma City				
Yankton, S. D.	7-10-07	1.92	3	509	Okl.	5-28-03	1.60	4	761
New Orleans, La.	8- 3-02	1.92	1	510	Columbia, Mo.	10-28-00	1.60	5	766
St. Paul, Minn.	10- 3-03	1.92	2	512	Des Moines, Ia.	7-16-07	1.60	5	771
New Orleans, La.	4-17-00	1.91	1	513	Chicago, Ill.	5-24-02	1.59	2	773
Kansas City, Mo.	6-22-01	1.90	7	520	New Orleans, La.	7-18-00	1.59	1	774
New Orleans, La.	11-22-01	1.90	1	521	Dodge City, Kans.	7-28-00	1.58	8	777
Evansville, Ind.	7-11-04	1.90	4	525	Cincinnati, O.	7-21-03	1.58	1	778
Hannibal, Mo.	9-25-98	1.89	5	530	Hannibal, Mo.	8- 8-99	1.56	5	783
Indianapolis, Ind.	8-19-06	1.89	2	532	Columbia, Mo.	10-16-05	1.56	5	788
New Orleans, La.	7-17-97	1.88	1	533	Louisville, Ky.	3-16-98	1.55	2	790
Ft. Worth, Tex.	7-28-06	1.88	3	536	Omaha, Neb.	8-26-03	1.54	5	795
Yankton, S. D.	5-24-06	1.88	3	539	Lincoln, Neb.	8- 4-02	1.54	6	801
					Ft. Smith, Ark.	9- 2-06	1.54	7	808

City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.	City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.
Bismarck, N. D....	6-4-05	1.53	1	809	Lincoln, Neb.....	5-24-03	1.42	6	896
Indianapolis, Ind..	5-29-00	1.53	2	811	Ft. Worth, Tex....	9-21-00	1.42	3	899
Bismarck, N. D....	6-16-97	1.53	1	812	Ft. Worth, Tex....	5-24-07	1.42	3	902
Louisville, Ky.....	6-15-02	1.52	2	814	Lincoln, Neb.....	9-14-06	1.42	6	908
Columbus, O.....	8-15-00	1.52	1	815	Des Moines, Ia....	7-23-00	1.40	3	913
St. Louis, Mo.....	5-6-00	1.51	1	819	Oklahoma City				
New Orleans, La..	11-9-98	1.51	1	820	Oklahoma City	9-11-06	1.40	1	917
Kansas City, Mo...	9-6-05	1.50	7	827	Yankton, S. D....	9-20-02	1.40	3	920
New Orleans, La..	7-5-02	1.50	1	828	Huron, S. D.....	8-4-00	1.40	2	922
St. Paul, Minn....	10-3-00	1.50	2	830	Hannibal, Mo.....	8-10-99	1.40	5	927
St. Louis, Mo.....	5-21-98	1.49	4	834	New Orleans, La..	10-7-00	1.38	1	928
New Orleans, La..	7-25-99	1.49	1	835	Lincoln, Neb.....	9-16-06	1.37	6	934
Topeka, Kans.....	7-31-02	1.48	7	842	Milwaukee, Wis...	9-14-03	1.34	2	936
Columbia, Mo.....	6-7-98	1.48	5	847	Kansas City, Mo...	7-19-06	1.30	7	943
Memphis, Tenn....	3-26-02	1.48	3	850	St. Paul, Minn....	8-4-05	1.28	2	945
Oklahoma City					Little Rock, Ark...	9-10-99	1.26	3	948
Oklahoma City	7-20-97	1.46	4	854	Milwaukee, Wis...	6-12-99	1.25	2	950
Oklahoma City					Des Moines, Ia....	5-21-03	1.24	5	955
Oklahoma City	5-6-00	1.46	4	858	Kansas City, Mo...	8-21-04	1.22	7	962
Chicago, Ill.....	7-9-03	1.44	2	860	Little Rock, Ark...	12-13-01	1.14	3	965
Omaha, Neb.....	6-16-00	1.44	5	865	Huron, S. D.....	5-9-05	1.09	2	967
Springfield, Ill...	8-3-05	1.44	1	871	Oklahoma City				
Springfield, Ill...	6-1-02	1.44	6	877	Oklahoma City	3-25-02	1.06	4	971
Kansas City, Mo...	7-5-04	1.44	7	884	Des Moines, Ia....	4-17-00	.93	5	976
Memphis, Tenn....	5-26-02	1.44	3	887	New Orleans, La..	4-25-07	.80	1	977
Dodge City, Kans..	10-9-98	1.42	3	890					

Table IV.

## HEAVY PRECIPITATIONS.

20 MINUTES.

City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.	City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.
Kansas City, Mo...	8-23-06	6.48	7	7	Little Rock, Ark...	5-21-98	3.66	3	166
New Orleans, La..	9-30-05	6.07	1	8	Memphis, Tenn...	6-7-05	3.64	3	169
New Orleans, La..	5-30-07	5.16	1	9	Springfield, Mo...	8-14-05	3.64	10	179
Cincinnati, O.....	5-20-02	5.03	1	10	Oklahoma City				
St. Louis, Mo.....	7-8-98	4.92	4	14	Oklahoma City	6-4-04	3.62	4	183
St. Paul, Minn....	8-9-02	4.92	2	16	New Orleans, La..	4-25-07	3.60	1	184
Hannibal, Mo.....	8-17-06	4.68	5	21	Indianapolis, Ind..	7-25-97	3.60	2	186
New Orleans, La..	8-25-04	4.65	1	22	New Orleans, La..	7-11-07	3.58	1	187
Milwaukee, Wis...	6-24-04	4.64	2	24	Cairo, Ill.....	6-13-99	3.58	3	190
Nashville, Tenn...	11-20-00	4.60	2	26	Topeka, Kans.....	9-13-01	3.56	7	197
Columbus, O.....	6-23-01	4.49	1	27	Davenport, Ia....	7-10-07	3.55	7	204
Des Moines, Ia....	7-19-04	4.41	5	32	Des Moines, Ia....	5-28-00	3.54	5	209
Omaha, Neb.....	7-6-98	4.24	5	37	Huron, S. D.....	6-14-01	3.54	2	211
Springfield, Mo...	5-31-06	4.24	10	47	Indianapolis, Ind..	8-9-99	3.52	1	213
Wichita, Kans....	9-17-05	4.20	10	57	Topeka, Kans....	6-24-03	3.48	7	220
Ft. Worth, Tex....	9-21-00	4.14	3	60	Kansas City, Mo...	6-22-06	3.46	7	227
Columbus, O.....	7-11-97	4.11	1	61	Cincinnati, O.....	7-22-05	3.43	1	228
Columbia, Mo.....	8-22-05	4.06	5	66	Denver, Colo.....	5-27-98	3.42	1	229
Nashville, Tenn...	8-21-02	4.02	2	68	New Orleans, La..	8-22-03	3.42	1	230
Davenport, Ia....	9-1-05	4.00	7	75	Kansas City, Mo...	9-14-05	3.40	7	237
Little Rock, Ark...	7-11-03	3.98	3	78	New Orleans, La..	7-15-01	3.40	1	238
New Orleans, La..	7-18-01	3.95	1	79	St. Louis, Mo....	8-6-07	3.40	4	242
Springfield, Mo...	7-26-05	3.92	10	89	Oklahoma City				
Nashville, Tenn...	6-15-97	3.92	2	91	Oklahoma City	5-29-05	3.38	4	246
Columbia, Mo...	5-31-02	3.90	11	102	Nashville, Tenn...	6-15-05	3.38	2	248
Cairo, Ill.....	6-28-05	3.84	3	105	Dodge City, Kans.	6-7-99	3.38	3	251
Hannibal, Mo.....	9-9-08	3.81	5	110	Davenport, Ia....	7-10-07	3.36	7	258
Huron, S. D.....	7-6-05	3.81	2	112	New Orleans, La..	4-17-01	3.36	1	259
Louisville, Ky....	8-8-98	3.80	2	114	Des Moines, Ia....	7-14-07	3.36	5	264
Ft. Worth, Tex....	6-3-04	3.78	3	117	New Orleans, La..	7-19-01	3.35	1	265
Columbia, Mo...	6-25-99	3.78	5	122	Columbia, Mo....	7-2-05	3.34	5	270
New Orleans, La..	3-17-04	3.77	1	123	Indianapolis, Ind..	9-30-02	3.34	2	272
Nashville, Tenn...	7-19-04	3.75	2	125	Dodge City, Kans.	6-4-98	3.34	3	275
Ft. Worth, Tex....	3-25-01	3.74	3	128	New Orleans, La..	3-14-03	3.33	1	276
Shreveport, La....	7-23-05	3.74	4	132	Topeka, Kans....	7-21-04	3.32	7	283
Topeka, Kans....	8-2-03	3.72	7	139	Chicago, Ill.....	7-15-06	3.30	2	285
Columbia, Mo...	8-25-00	3.72	5	144	Lexington, Ky....	8-22-00	3.30	1	286
Wichita, Kans....	7-6-04	3.72	10	154	Louisville, Ky....	5-31-03	3.29	2	288
Ft. Worth, Tex....	7-2-05	3.70	3	157	Nashville, Tenn...	9-1-00	3.29	2	290
Lincoln, Neb.....	8-15-00	3.68	6	163	Dubuque, Ia....	8-15-07	3.28	5	295

(298 weighted rains every 5 years.)

City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.	City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.
Columbia, Mo.....	9-16-05	3.26	5	300	Hannibal, Mo.....	9-25-98	2.92	5	546
Nashville, Tenn....	6-7-00	3.26	2	302	Bismarck, N. D....	6-16-97	2.92	1	547
St. Louis, Mo.....	5-1-99	3.25	4	306	Evansville, Ind....	7-20-04	2.92	4	551
St. Louis, Mo.....	5-4-02	3.25	4	310	Indianapolis, Ind..	3-31-04	2.92	2	553
Little Rock, Ark....	5-8-00	3.24	3	313	Davenport, Ia.....	9-25-04	2.91	7	560
Huron, S. D.....	6-12-00	3.24	2	315	New Orleans, La....	8-5-07	2.91	1	561
Shreveport, La....	6-1-06	3.24	4	319	Ft. Worth, Tex....	5-11-05	2.90	3	564
Dodge City, Kas....	8-6-98	3.22	3	322	St. Paul, Minn....	9-25-06	2.90	2	566
Milwaukee, Wis....	9-2-00	3.22	2	324	Yankton, S. D....	8-18-99	2.90	3	569
New Orleans, La....	3-30-99	3.22	1	325	New Orleans, La....	9-16-01	2.90	1	570
Chicago, Ill.....	8-5-05	3.20	2	327	Evansville, Ind....	9-2-04	2.90	4	574
Wichita, Kans.....	7-14-04	3.20	10	337	Denver, Colo.....	6-2-00	2.88	1	575
Davenport, Ia.....	9-1-05	3.20	7	344	Hannibal, Mo.....	5-26-06	2.88	5	580
St. Louis, Mo.....	7-24-00	3.20	4	348	Little Rock, Ark....	11-28-05	2.88	3	583
Dodge City, Kas....	8-18-04	3.20	3	351	Dodge City, Kas....	7-23-99	2.88	3	586
Lincoln, Neb.....	8-17-97	3.19	6	357	Columbus, O.....	7-28-02	2.88	1	587
Shreveport, La....	4-11-05	3.18	4	361	Evansville, Ind....	8-14-06	2.86	4	591
Des Moines, Ia....	7-19-05	3.18	5	366	Hannibal, Mo.....	8-8-99	2.86	5	596
St. Louis, Mo.....	6-13-00	3.18	4	370	Dodge City, Kas....	6-7-99	2.86	3	599
Indianapolis, Ind..	8-19-01	3.18	2	372	St. Paul, Minn....	9-5-04	2.86	2	601
New Orleans, La....	7-11-04	3.17	1	373	Omaha, Neb.....	7-18-07	2.85	5	606
New Orleans, La....	12-22-07	3.17	1	374	Valentine, Neb....	7-21-04	2.84	3	609
New Orleans, La....	8-22-03	3.16	1	375	Shreveport, La....	7-23-02	2.84	4	613
Springfield, Ill....	8-7-07	3.16	6	381	New Orleans, La....	8-5-98	2.84	1	614
Little Rock, Ark....	9-15-98	3.16	3	384	Columbia, Mo.....	6-14-98	2.83	5	619
Lincoln, Neb.....	7-15-00	3.16	6	390	Chicago, Ill.....	5-11-05	2.82	2	621
Denver, Colo.....	9-20-02	3.16	1	391	Shreveport, La....	6-27-02	2.82	4	625
New Orleans, La....	3-14-03	3.15	1	392	Oklahoma City				
Cairo, Ill.....	8-7-06	3.14	3	395	Oklahoma City	8-28-00	2.81	4	629
Evansville, Ind....	9-2-00	3.14	4	399	Dodge City, Kas....	7-19-97	2.80	3	632
New Orleans, La....	7-10-07	3.14	1	400	Memphis, Tenn....	6-23-99	2.80	3	635
Nashville, Tenn....	6-28-00	3.13	2	402	Columbia, Mo.....	7-31-99	2.80	5	641
Lincoln, Neb.....	4-23-97	3.12	6	408	Columbia, Mo.....	9-18-04	2.80	5	646
New Orleans, La....	7-6-04	3.11	1	409	Topeka, Kans.....	7-28-01	2.79	7	653
Yankton, S. D....	7-15-00	3.10	3	412	Springfield, Mo....	7-19-06	2.79	10	663
Hannibal, Mo.....	8-13-04	3.10	5	417	Indianapolis, Ind..	8-12-00	2.78	2	665
New Orleans, La....	6-22-03	3.10	1	418	Kansas City, Mo....	8-21-04	2.78	7	672
St. Paul, Minn....	10-3-03	3.10	2	420	Columbus, O.....	6-14-04	2.77	1	673
Huron, S. D.....	6-27-05	3.10	2	422	Huron, S. D.....	8-8-01	2.77	2	675
Ft. Worth, Tex....	6-5-07	3.10	3	425	New Orleans, La....	4-25-07	2.77	1	676
Wichita, Kans....	8-1-03	3.10	10	435	Kansas City, Mo....	5-23-02	2.76	7	683
Hannibal, Mo.....	9-4-98	3.09	5	440	New Orleans, La....	6-27-04	2.76	1	684
Ft. Worth, Tex....	6-20-06	3.08	3	443	Lincoln, Neb.....	5-28-05	2.75	6	690
Oklahoma City					Nashville, Tenn....	6-9-03	2.75	2	692
Oklahoma City	9-11-06	3.08	4	447	Shreveport, La....	5-3-06	2.75	4	696
Lexington, Ky.....	7-28-04	3.08	1	448	Ft. Worth, Tex....	6-24-03	2.74	3	699
Dodge City, Kas....	6-17-06	3.08	3	451	Little Rock, Ark....	6-1-98	2.74	3	702
Nashville, Tenn....	9-4-06	3.07	2	453	Kansas City, Mo....	7-14-07	2.74	7	709
Evansville, Ind....	5-8-00	3.06	4	457	Huron, S. D.....	6-24-02	2.74	2	711
Ft. Worth, Tex....	7-28-06	3.06	3	460	Dodge City, Kas....	8-16-07	2.74	3	714
New Orleans, La....	8-24-03	3.06	1	461	New Orleans, La....	6-7-04	2.74	1	715
Memphis, Tenn....	8-9-05	3.06	3	464	Omaha, Neb.....	6-26-06	2.74	5	720
Ft. Worth, Tex....	5-2-06	3.04	3	467	New Orleans, La....	3-14-03	2.74	1	721
Huron, S. D.....	8-8-04	3.04	2	469	Indianapolis, Ind..	8-19-06	2.73	2	723
New Orleans, La....	6-4-05	3.03	1	470	New Orleans, La....	7-11-06	2.71	1	724
Wichita, Kans....	6-15-05	3.00	10	480	Topeka, Kans.....	8-26-02	2.71	7	731
Memphis, Tenn....	3-9-01	3.00	2	482	Hannibal, Mo.....	6-4-04	2.70	5	736
Yankton, S. D....	8-23-06	3.00	3	485	Valentine, Neb....	7-6-07	2.70	3	739
Little Rock, Ark....	5-12-05	2.98	3	488	Lincoln, Neb.....	8-4-07	2.70	6	745
St. Paul, Minn....	6-28-01	2.98	2	490	Kansas City, Mo....	7-2-05	2.70	7	752
Lexington, Ky.....	8-23-05	2.98	1	491	Wichita, Kans....	5-20-03	2.68	10	762
Bismarck, N. D....	6-13-01	2.97	1	492	Kansas City, Mo....	6-22-01	2.68	7	769
Yankton, S. D....	7-14-00	2.96	3	495	New Orleans, La....	8-12-06	2.68	1	770
Oklahoma City					Louisville, Ky.....	7-10-97	2.68	2	772
Oklahoma City	5-5-99	2.96	4	499	New Orleans, La....	6-20-00	2.68	1	773
Kansas City, Mo....	5-24-05	2.96	7	506	New Orleans, La....	7-4-03	2.67	1	774
Kansas City, Mo....	8-2-05	2.96	7	513	St. Paul, Minn....	6-14-01	2.66	2	776
Chicago, Ill.....	7-28-06	2.96	2	515	Shreveport, La....	5-21-05	2.66	4	780
Evansville, Ind....	8-5-03	2.96	4	519	Milwaukee, Wis....	8-23-98	2.65	2	782
Lincoln, Neb.....	7-31-03	2.96	6	525	Indianapolis, Ind..	7-6-04	2.64	2	784
La Crosse, Wis....	7-9-03	2.96	5	530	Davenport, Ia.....	9-9-03	2.64	7	791
Nashville, Tenn....	7-10-97	2.95	2	532	Yankton, S. D....	7-10-07	2.64	3	794
Huron, S. D.....	7-20-07	2.95	2	534	Bismarck, N. D....	10-1-98	2.63	1	795
St. Louis, Mo.....	7-4-99	2.94	1	538	Lexington, Ky.....	5-10-05	2.63	1	796
New Orleans, La....	8-25-03	2.94	1	539	Dodge City, Kas....	7-21-07	2.62	3	799
Chicago, Ill.....	7-1-01	2.92	2	541	New Orleans, La....	4-17-00	2.62	1	800

City.	Date.	Av. Rate per hr.	Par- Final Wt. Tls.	City.	Date.	Av. Rate per hr.	Par- Final Wt. Tls.
Valentine, Neb....	6-27-05	2.62	3 803	Yankton, S. D....	5-24-06	2.32	3 1106
La Crosse, Wis....	7-21-07	2.62	5 808	Omaha, Neb.....	7-15-00	2.32	5 1111
Wichita, Kans....	6- 2-04	2.62	10 818	Valentine, Neb....	7- 9-07	2.32	3 1114
St. Louis, Mo....	5-21-98	2.62	4 822	Shreveport, La....	5- 7-07	2.32	4 1118
Wichita, Kans....	8-16-07	2.61	10 832	Springfield, Mo....	6-24-06	2.31	10 1128
Kansas City, Mo....	8-15-03	2.61	7 839	New Orleans, La..	7-18-00	2.31	1 1129
Oklahoma City				Evansville, Ind....	5-31-07	2.30	4 1133
Okla. ....	5- 6-99	2.61	4 843	Columbia, Mo....	7-18-02	2.30	5 1138
Nashville, Tenn....	7-11-97	2.61	2 845	Little Rock, Ark....	9-10-99	2.30	3 1141
Evansville, Ind....	7-11-04	2.60	4 849	New Orleans, La..	7-17-97	2.29	1 1142
St. Louis, Mo....	5-31-03	2.60	4 853	Lincoln, Neb....	9-14-06	2.28	6 1148
Memphis, Tenn....	8-30-97	2.60	3 856	Yankton, S. D....	9-20-02	2.28	3 1151
Indianapolis, Ind..	8- 2-99	2.60	2 858	Columbus, O.....	7-19-00	2.28	1 1152
Wichita, Kans....	6- 2-05	2.59	10 865	Nashville, Tenn....	6-27-04	2.28	2 1154
Oklahoma City				Omaha, Neb.....	6-16-00	2.26	5 1159
Okla. ....	5-28-03	2.58	4 872	Chicago, Ill.....	5-24-02	2.26	2 1161
Ft. Smith, Ark....	8-26-04	2.58	7 879	Des Moines, Ia....	7-23-00	2.25	5 1166
Little Rock, Ark....	7-29-00	2.58	3 882	Dodge City, Kans..	10- 9-98	2.24	3 1169
Davenport, Ia....	9-14-03	2.58	7 889	Hannibal, Mo....	8- 8-99	2.24	5 1174
St. Paul, Minn....	8- 5-98	2.58	2 891	Lincoln, Neb....	8- 7-07	2.24	6 1180
Des Moines, Ia....	4-22-97	2.57	5 896	Indianapolis, Ind..	5-29-00	2.23	2 1182
Kansas City, Mo....	7- 7-02	2.57	7 903	New Orleans, La..	8- 3-98	2.23	1 1183
Kansas City, Mo....	3-24-04	2.56	7 910	St. Paul, Minn....	6-12-99	2.22	2 1185
Hannibal, Mo....	7- 4-99	2.56	5 915	Oklahoma City			
Springfield, Ill....	5- 5-01	2.56	6 921	Okla. ....	3-25-02	2.22	4 1189
Columbia, Mo....	5-25-03	2.56	5 926	Des Moines, Ia....	4-17-00	2.21	5 1194
Kansas City, Mo....	9- 5-98	2.56	7 933	New Orleans, La..	9- 9-98	2.18	1 1195
Cairo, Ill.....	6- 7-00	2.56	3 936	Dubuque, Ia....	9-25-04	2.18	5 1200
Ft. Worth, Tex....	5- 3-04	2.54	3 939	St. Paul, Minn....	8- 4-05	2.18	2 1202
Lexington, Ky....	7-19-02	2.54	1 940	Des Moines, Ia....	7-16-07	2.18	5 1207
Shreveport, La....	4- 2-05	2.54	4 944	New Orleans, La..	7-25-99	2.17	1 1208
Bismarck, N. D....	6- 4-05	2.54	1 945	Des Moines, Ia....	7-18-04	2.17	5 1213
Columbia, Mo....	10-16-05	2.53	5 950	Columbia, Mo....	4-24-04	2.16	5 1218
Columbia, Mo....	4-25-02	2.52	5 955	La Crosse, Wis....	8- 4-05	2.14	5 1223
Lincoln, Neb....	7-22-02	2.52	6 961	Topeka, Kans....	7-31-02	2.12	7 1230
Evansville, Ind....	7-10-05	2.52	4 965	Cincinnati, O.....	7-21-03	2.12	1 1231
New Orleans, La..	3-19-05	2.50	1 966	Chicago, Ill.....	7- 9-03	2.12	2 1233
Memphis, Tenn....	11-19-06	2.50	3 969	Louisville, Ky....	6-15-02	2.12	2 1235
Cincinnati, O.....	5-29-99	2.50	1 970	Yankton, S. D....	9-20-02	2.08	3 1238
Memphis, Tenn....	8-18-01	2.48	3 973	St. Paul, Minn....	10- 3-00	2.08	2 1240
New Orleans, La..	7- 7-98	2.48	1 974	Huron, S. D....	8-18-04	2.07	2 1242
Evansville, Ind....	6- 2-04	2.48	4 978	Oklahoma City			
Columbus, O.....	7-20-97	2.48	1 979	Okla. ....	5- 6-00	2.05	4 1246
Kansas City, Mo....	9- 9-03	2.48	7 986	Cairo, Ia.....	7-30-01	2.04	3 1249
New Orleans, La..	11-22-01	2.48	1 987	Dodge City, Kans.	7-28-00	2.02	4 1252
Oklahoma City				Oklahoma City			
Okla. ....	8-11-02	2.46	4 991	Okla. ....	8-12-01	2.00	4 1256
Cincinnati, O.....	8- 3-00	2.46	1 992	Springfield, Ill....	8- 3-05	2.00	10 1262
Milwaukee, Wis....	7-21-07	2.46	2 994	Springfield, Mo....	8- 7-06	2.00	10 1272
Little Rock, Ark....	8-25-99	2.46	3 997	Columbia, Mo....	6- 7-98	1.98	5 1277
Little Rock, Ark....	6-22-04	2.46	3 1000	Indianapolis, Ind..	6- 4-06	1.97	2 1279
Springfield, Mo....	6- 4-04	2.45	10 1010	Ft. Worth, Tex....	9-21-00	1.96	3 1282
New Orleans, La..	5-23-07	2.45	1 1011	St. Paul, Minn....	7-25-97	1.94	2 1284
Columbia, Mo....	10-28-00	2.44	5 1016	Little Rock, Ark....	7-29-03	1.94	2 1287
Lincoln, Neb....	8- 4-02	2.44	6 1022	Topeka, Kans....	8- 4-06	1.93	7 1294
Topeka, Kans....	9-22-02	2.42	7 1029	Omaha, Neb.....	8-26-03	1.92	5 1299
Oklahoma City				Kansas City, Mo....	7- 5-04	1.92	7 1306
Okla. ....	5-23-03	2.42	4 1033	New Orleans, La..	11- 9-98	1.90	1 1307
Oklahoma City				Oklahoma City			
Okla. ....	8- 7-06	2.42	4 1037	Okla. ....	5-21-03	1.90	4 1311
Ft. Worth, Tex....	10-21-00	2.42	3 1040	Milwaukee, Wis....	6-12-99	1.90	2 1313
St. Paul, Minn....	8-18-07	2.42	2 1042	Ft. Worth, Tex....	5-24-07	1.86	3 1316
Evansville, Ind....	5-30-00	2.42	4 1046	Huron, S. D....	8- 4-00	1.85	2 1318
Cairo, Ill.....	6-22-97	2.42	3 1049	Des Moines, Ia....	5-21-03	1.84	5 1323
Little Rock, Ark....	4-24-05	2.40	3 1052	Ft. Smith, Ark....	9- 2-06	1.82	7 1330
Springfield, Ill....	6- 1-02	2.40	5 1057	Nashville, Tenn....	9-14-01	1.80	2 1332
St. Louis, Mo....	7-29-03	2.40	4 1061	Dodge City, Kans.	8- 6-03	1.80	3 1336
St. Louis, Mo....	5- 5-00	2.39	4 1065	Hannibal, Mo....	7- 7-98	1.76	5 1340
Wichita, Kans....	10-30-03	2.38	10 1075	New Orleans, La..	10- 7-00	1.76	1 1341
Columbia, Mo....	10- 6-00	2.37	5 1080	Lincoln, Neb....	5-10-05	1.76	6 1347
Valentine, Neb....	7-11-06	2.36	3 1083	Dodge City, Kans.	5-13-98	1.72	3 1350
Ft. Worth, Tex....	8-11-06	2.36	3 1086	Columbus, O.....	8-15-00	1.72	1 1351
New Orleans, La..	8- 3-02	2.34	1 1087	Hannibal, Mo....	8-10-99	1.64	5 1356
Kansas City, Mo....	9- 6-05	2.34	7 1094	New Orleans, La..	7- 5-02	1.63	1 1357
St. Paul, Minn....	7-30-04	2.32	2 1096	Louisville, Ky....	3-16-98	1.60	2 1359
Kansas City, Mo....	7-19-06	2.32	7 1103	Huron, S. D....	6- 9-05	1.58	2 1361

City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.	City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.
Lincoln, Neb.....	5-24-03	1.55	6	1367	Little Rock, Ark...	12-31-01	1.44	3	1374
Oklahoma City					New Orleans, La...	4-25-07	1.26	1	1875
Okla. ....	7-20-97	1.44	4	1371	Lincoln, Neb.....	9-16-06	1.10	6	1381

Table V.  
HEAVY PRECIPITATIONS.  
10 MINUTES.

City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.	City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.
Huron, S. D.....	6-14-01	7.34	2	2	New Orleans, La...	8-25-03	4.38	1	218
New Orleans, La...	9-30-05	7.06	1	3	St. Louis, Mo....	5- 1-99	4.38	4	222
Kansas City, Mo...	8-23-06	6.78	7	10	Springfield, Mo...	7-26-05	4.38	10	232
New Orleans, La...	5-30-07	6.50	1	11	Nashville, Tenn...	7-19-04	4.37	2	234
Des Moines, Ia...	7-19-04	6.12	5	16	Yankton, S. D....	7-15-00	4.36	3	237
St. Louis, Mo....	7- 8-98	6.03	4	20	Yankton, S. D....	8-18-99	4.35	8	240
Springfield, Mo...	5-31-06	6.01	10	30	Wichita, Kans....	7- 6-04	4.35	10	250
New Orleans, La...	8-25-04	5.93	1	31	Louisville, Ky...	8- 8-98	4.35	2	252
Indianapolis, Ind.	9-30-02	5.84	2	33	New Orleans, La...	7- 6-04	4.31	1	253
Milwaukee, Wis...	6-24-04	5.78	2	35	Lincoln, Neb.....	7-31-03	4.31	6	259
Hannibal, Mo....	8-17-06	5.64	5	40	Nashville, Tenn...	6-15-05	4.30	2	261
Columbia, Mo....	7- 2-05	5.62	5	45	Kansas City, Mo...	6-22-06	4.30	7	268
Cincinnati, O....	5-20-02	5.61	1	46	Lincoln, Neb....	7-15-00	4.28	6	274
Wichita, Kans....	9-17-05	5.50	10	56	New Orleans, La...	3-30-99	4.27	1	275
Omaha, Neb.....	7- 6-98	5.46	5	61	St. Louis, Mo....	5- 4-02	4.26	4	279
Columbus, O....	6-23-01	5.39	1	62	Lincoln, Neb....	8-17-97	4.26	6	285
Louisville, Ky...	5-31-03	5.36	2	64	Topeka, Kans....	9-13-01	4.24	7	292
St. Paul, Minn...	8- 9-02	5.30	2	66	Hannibal, Mo....	8-13-04	4.24	5	297
Memphis, Tenn...	3- 9-01	5.28	3	69	Ft. Worth, Tex...	7-28-06	4.22	3	300
Hannibal, Mo....	5-26-06	5.23	5	74	Dodge City, Kans.	6- 4-98	4.22	3	303
Nashville, Tenn...	11-20-00	5.22	2	76	Oklahoma City				
Milwaukee, Wis...	9-17-07	5.20	2	78	Okla. ....	6- 4-04	4.18	4	307
Denver, Colo....	5-27-98	5.02	1	79	New Orleans, La...	6-22-03	4.18	1	308
Columbia, Mo....	6-25-99	5.02	5	84	Little Rock, Ark...	5- 8-00	4.16	8	311
Hannibal, Mo....	9- 4-98	4.97	5	89	Ft. Worth, Tex...	6-20-06	4.16	3	314
Indianapolis, Ind.	8- 9-99	4.96	2	91	Little Rock, Ark...	5-12-05	4.14	3	317
St. Louis, Mo....	6-13-00	4.94	4	95	Lexington, Ky...	7-28-04	4.14	1	318
Ft. Worth, Tex...	9-21-00	4.90	3	98	Ft. Worth, Tex...	6- 5-07	4.14	3	321
Davenport, Ia...	8-26-07	4.89	7	105	New Orleans, La...	4-25-07	4.14	1	322
Lincoln, Neb....	8-15-00	4.82	6	111	Indianapolis, Ind.	7-25-97	4.13	2	324
Huron, S. D.....	7- 6-05	4.80	2	113	Topeka, Kans....	7-21-04	4.13	7	331
New Orleans, La...	7-15-01	4.80	1	114	Indianapolis, Ind.	8-19-01	4.12	2	333
Chicago, Ill.....	8- 5-05	4.76	2	116	New Orleans, La...	7-19-01	4.08	1	334
Cairo, Ill.....	6-28-05	4.74	3	119	Valentine, Neb...	8- 2-04	4.08	3	337
Davenport, Ia...	6- 9-05	4.72	7	126	Cairo, Ill.....	6-13-99	4.06	3	340
Ft. Worth, Tex...	3-25-04	4.72	3	129	Cincinnati, O....	7-22-06	4.05	1	341
Ft. Worth, Tex...	7- 2-05	4.70	3	132	Evansville, Ind...	7-11-04	4.04	4	345
Des Moines, Ia...	7-19-05	4.67	5	137	Evansville, Ind...	5- 8-00	4.02	4	349
Columbia, Mo....	8-22-05	4.64	5	142	Topeka, Kans....	8- 2-03	4.02	7	356
New Orleans, La...	3-17-04	4.62	1	143	New Orleans, La...	4-25-07	3.99	1	357
Nashville, Tenn...	6-15-97	4.61	2	145	Shreveport, La...	6- 1-06	3.98	1	358
Des Moines, Ia...	5-28-00	4.60	5	150	Bismarck, N. D...	6-13-01	3.98	1	359
Columbus, O....	7-11-97	4.57	1	151	New Orleans, La...	7-10-07	3.97	1	360
New Orleans, La...	7-18-01	4.57	1	152	Davenport, Ia...	9-25-04	3.96	7	367
Evansville, Ind...	8- 5-03	4.56	4	156	Topeka, Kans....	6-24-03	3.96	7	374
Chicago, Ill.....	7-15-06	4.53	2	161	Ft. Worth, Tex...	5- 2-06	3.94	3	377
Ft. Worth, Tex...	6- 3-04	4.52	3	159	Huron, S. D.....	8- 8-04	3.93	2	379
Nashville, Tenn...	8-21-02	4.52	2	171	New Orleans, La...	8- 5-07	3.92	1	380
Hannibal, Mo....	9- 9-03	4.51	5	166	St. Paul, Minn...	8- 5-98	3.92	2	382
Dodge City, Kans.	6- 6-98	4.50	3	169	Des Moines, Ia...	7-14-07	3.92	5	387
New Orleans, La...	4-17-01	4.50	1	172	Oklahoma City				
La Crosse, Wis...	7- 9-03	4.50	5	177	Okla. ....	5- 6-00	3.92	4	391
Columbia, Mo....	5-31-02	4.49	5	182	Nashville, Tenn...	6- 7-00	3.91	2	393
Nashville, Tenn...	7-10-97	4.48	2	184	Columbia, Mo....	6-14-98	3.90	5	398
Columbia, Mo....	8-25-00	4.46	5	189	Topeka, Kans....	9-22-02	3.90	7	405
Nashville, Tenn...	6-28-00	4.45	2	191	Dodge City, Kans.	6- 7-99	3.90	3	408
St. Louis, Mo....	8- 6-07	4.44	1	195	Columbus, O....	6-14-04	3.89	1	409
Columbia, Mo....	9-16-05	4.42	5	200	Little Rock, Ark...	9-15-98	3.88	3	412
Little Rock, Ark...	7-11-03	4.42	3	203	Dodge City, Kans.	8-18-04	3.88	3	415
Dodge City, Kans.	6-17-06	4.42	3	206	Dodge City, Kans.	6- 7-99	3.88	3	418
New Orleans, La...	12-22-07	4.41	1	207	Wichita, Kans....	8- 1-03	3.88	10	428
Davenport, Ia...	7-10-07	4.40	7	214	New Orleans, La...	3-14-03	3.88	1	429
Little Rock, Ark...	5-21-98	4.38	3	217	Cincinnati, O....	5-29-99	3.87	1	430

City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.	City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.
Shreveport, La....	7-23-05	3.86	4	434	Indianapolis, Ind..	7- 6-04	3.60	2	591
Memphis, Tenn....	6- 7-05	3.86	3	437	O k l a h o m a City				
Cairo, Ill.....	8- 7-06	3.86	3	440	Oklahoma.....	5-29-05	3.60	4	595
Indianapolis, Ind..	8-12-00	3.85	2	442	Denver, Colo.....	9-20-02	3.60	1	596
New Orleans, La..	6-20-00	3.84	1	443	Ft. Smith, Ark....	8-26-04	3.58	7	603
St. Louis, Mo....	7-24-00	3.84	4	447	Des Moines, Ia....	7-16-07	3.57	5	608
Springfield, Ill....	8- 7-07	3.83	4	453	Dodge City, Kans.	7-21-07	3.56	3	611
Huron, S. D.....	7-20-07	3.83	2	455	Shreveport, La....	6-27-02	3.56	4	615
Chicago, Ill.....	7-28-06	3.82	2	457	La Crosse, Wis....	7-21-07	3.56	5	620
O k l a h o m a City					Little Rock, Ark..	11-28-05	3.56	3	623
Oklahoma.....	5- 6-99	3.81	4	461	Columbia, Mo.....	9-18-04	3.54	5	628
St. Paul, Minn....	6-28-01	3.80	2	463	Evansville, Ind....	9- 2-00	3.54	4	632
St. Paul, Minn....	9- 5-04	3.80	2	465	New Orleans, La..	6-27-04	3.54	1	633
New Orleans, La..	4-17-00	3.80	1	466	Milwaukee, Wis....	9- 2-00	3.54	2	635
Dodge City, Kans.	7-23-99	3.78	3	469	New Orleans, La..	3-14-03	3.54	1	636
St. Louis, Mo....	7- 4-99	3.78	4	473	Indianapolis, Ind..	3-31-04	3.53	2	638
Lexington, Ky....	8-23-05	3.78	1	474	Shreveport, La....	4- 2-05	3.53	4	642
New Orleans, La..	7-11-07	3.77	1	475	St. Paul, Minn....	8- 4-05	3.52	2	644
Wichita, Kans....	6- 2-04	3.76	10	485	Omaha, Neb.....	7-13-07	3.52	5	640
Kansas City, Mo..	9- 5-98	3.76	7	492	Wichita, Kans....	6- 2-05	3.52	10	659
Davenport, Ia....	9- 1-05	3.75	7	499	Wichita, Kans....	8-16-07	3.50	10	669
O k l a h o m a City					Wichita, Kans....	5-20-03	3.50	10	679
Oklahoma.....	8-28-00	3.75	4	503	Kansas City, Mo..	8-21-04	3.50	7	686
Davenport, Ia....	9-14-03	3.74	7	510	O k l a h o m a City				
Lexington, Ky....	8-22-00	3.72	1	511	Oklahoma.....	5- 5-99	3.50	4	690
Columbia, Mo.....	10-16-05	3.72	5	516	Bismarck, N. D..	6- 4-05	3.50	1	691
New Orleans, La..	7-11-04	3.70	1	517	Dubuque, Ia....	8-15-07	3.50	5	696
Columbia, Mo.....	7-31-99	3.69	5	522	Indianapolis, Ind..	8-19-06	3.49	2	698
Ft. Worth, Tex....	5-11-05	3.68	3	523	Kansas City, Mo..	5-24-05	3.48	7	705
Kansas City, Mo..	8- 2-05	3.67	7	530	Cincinnati, O.....	7- 5-97	3.46	1	706
Hannibal, Mo.....	9-25-98	3.67	5	535	Columbus, O.....	7-28-02	3.46	1	707
Wichita, Kans....	7-14-04	3.66	10	545	O k l a h o m a City				
Kansas City, Mo..	9-14-05	3.66	7	552	Oklahoma.....	9-11-06	3.46	4	711
Yankton, S. D....	7- 8-98	3.66	3	555	Nashville, Tenn....	9- 4-06	3.45	2	713
New Orleans, La..	3-14-03	3.66	1	556	Hannibal, Mo.....	7- 7-98	3.44	5	718
Wichita, Kans....	6-15-05	3.64	10	566	Indianapolis, Ind..	8- 2-99	3.44	2	720
New Orleans, La..	8-12-06	3.63	1	567	Nashville, Tenn....	9- 1-00	3.44	2	722
New Orleans, La..	8-22-03	3.62	1	568	Evansville, Ind....	6- 2-04	3.44	4	726
Valentine, Neb....	7-21-04	3.62	3	571	Huron, S. D.....	8- 8-01	3.44	2	728
St. Paul, Minn....	6-14-01	3.62	2	573	Dodge City, Kans.	8-16-07	3.44	3	731
Yankton, S. D....	5-24-06	3.62	3	576	Yankton, S. D....	7-14-00	3.43	3	734
Topeka, Kans....	8-26-02	3.61	7	583	Lincoln, Neb.....	8- 4-02	3.42	6	740
Lincoln, Neb.....	4-23-97	3.60	6	589	Omaha, Neb.....	6-26-06	3.42	5	745

(745 weighted rains every 2 years.)

City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.	City.	Date.	Av. Rate per hr.	Final Wt.	Par- tial Tls.
Springfield, Mo...	8-14-05	3.42	10	755	O k l a h o m a City				
St. Paul, Minn....	9-25-06	3.42	2	757	Oklahoma.....	8- 7-06	3.28	4	839
New Orleans, La..	8-24-03	3.42	1	758	Shreveport, La....	5- 3-06	3.28	4	843
Chicago, Ill.....	5-11-05	3.42	2	760	Chicago, Ill.....	7- 1-01	3.28	2	845
Huron, S. D.....	6-27-05	3.41	2	762	Shreveport, La....	7-23-02	3.27	4	852
Ft. Worth, Tex....	5- 3-04	3.40	3	765	Valentine, Neb....	7-11-06	3.26	3	848
Milwaukee, Wis....	8-23-98	3.39	2	767	Kansas City, Mo..	5-23-02	3.26	7	859
Ft. Smith, Ark....	6-30-07	3.39	7	774	Nashville, Tenn....	7-11-97	3.25	2	861
Springfield, Mo..	7-19-06	3.38	10	784	Topeka, Kans....	7-28-01	3.24	7	868
Memphis, Tenn....	8- 9-05	3.38	3	787	Little Rock, Ark..	8-25-99	3.24	3	871
St. Louis, Mo....	5-31-03	3.37	4	791	Evansville, Ind....	8-14-06	3.22	4	875
Kansas City, Mo..	3-24-04	3.36	7	793	Little Rock, Ark..	7-29-00	3.22	3	878
New Orleans, La..	8-22-03	3.35	1	799	St. Paul, Minn....	10- 3-03	3.22	2	880
Lexington, Ky....	5-10-05	3.35	1	800	New Orleans, La..	6- 4-05	3.22	1	881
Memphis, Tenn....	11-19-06	3.34	3	803	St. Louis, Mo....	5- 5-00	3.21	4	885
Yankton, S. D....	8-23-06	3.34	3	806	Yankton, S. D....	7-10-07	3.20	3	888
Evansville, Ind..	7-20-04	3.34	4	810	Kansas City, Mo..	7-19-06	3.20	7	895
Shreveport, La....	5-21-05	3.33	4	814	Kansas City, Mo..	9- 6-05	3.20	7	902
New Orleans, La..	9-16-01	3.33	1	815	Nashville, Tenn....	6-27-04	3.18	2	904
Bismarck, N. D..	10- 1-93	3.33	1	816	Little Rock, Ark..	4-24-05	3.18	3	907
Huron, S. D.....	6-24-02	3.33	2	818	Springfield, Mo..	6- 4-04	3.18	10	917
Louisville, Ky....	7-10-97	3.32	2	820	Columbia, Mo.....	10-28-00	3.18	5	922
Des Moines, Ia....	4-22-97	3.32	5	825	Columbus, O.....	7-19-00	3.17	1	923
Shreveport, La....	5- 7-07	3.31	4	829	Lexington, Ky....	7-19-02	3.16	1	924
Cincinnati, O.....	8- 3-00	3.30	1	830	St. Louis, Mo....	5-21-98	3.15	4	928
Dodge City, Kan.	7-19-97	3.30	3	833	Valentine, Neb....	7- 9-07	3.14	3	931
Huron, S. D.....	6-12-00	3.30	2	835	Little Rock, Ark..	6-22-04	3.14	3	934

City.	Date.	Av. Rate per hr.	Par- Final Wt. Tls.	City.	Date.	Av. Rate per hr.	Par- Final Wt. Tls.
Nashville, Tenn...	6- 9-03	3.13	2 936	New Orleans, La...	10- 7-00	2.80	1 1165
New Orleans, La...	6- 7-04	3.12	1 937	New Orleans, La...	5-23-07	2.80	1 1166
Memphis, Tenn...	7-16-06	3.12	3 940	Columbia, Mo...	10- 6-00	2.78	5 1171
Oklahoma City				St. Louis, Mo...	7-29-03	2.78	4 1175
Oklahoma City	5-28-03	3.12	4 944	St. Paul, Minn...	7-30-04	2.78	2 1177
Columbia, Mo...	5-25-03	3.12	5 949	Milwaukee, Wis...	7-21-07	2.76	2 1179
Kansas City, Mo...	6-22-01	3.12	7 956	Ft. Worth, Tex...	5-24-07	2.74	3 1182
Des Moines, Ia...	4-17-00	3.12	5 961	Yankton, S. D...	9-20-02	2.73	3 1185
Columbus, O...	7-20-97	3.10	1 962	Hannibal, Mo...	6- 4-04	2.73	5 1190
Oklahoma City				Milwaukee, Wis...	9-14-03	2.72	2 1192
Oklahoma City	3-25-02	3.10	4 966	Dodge City, Kans.	7-28-00	2.72	3 1195
Springfield, Mo...	6-24-06	3.10	10 976	New Orleans, La...	7- 4-03	2.72	1 1196
Lincoln, Neb...	8- 4-07	3.10	6 982	Dubuque, Ia...	9-25-04	2.72	5 1201
Columbia, Mo...	4-25-02	3.09	5 987	Davenport, Ia...	9- 9-03	2.70	7 1208
Huron, S. D...	6-17-04	3.08	2 989	La Crosse, Wis...	8- 4-05	2.70	5 1213
New Orleans, La...	11-22-01	3.08	1 990	St. Paul, Minn...	8-18-07	2.70	2 1215
Dodge City, Kans...	10- 9-98	3.08	3 993	St. Paul, Minn...	7-25-97	2.70	2 1217
New Orleans, La...	7-11-06	3.07	1 994	Little Rock, Ark...	7-29-03	2.68	3 1220
Valentine, Neb...	7- 6-07	3.06	3 997	Valentine, Neb...	6-27-05	2.68	3 1223
Wichita, Kans...	10-30-03	3.04	10 1007	Oklahoma City			
New Orleans, La...	11- 9-98	3.02	1 1008	Oklahoma City	5-21-03	2.68	4 1227
Columbia, Mo...	4-24-04	3.02	5 1013	Dodge City, Kans.	8- 6-03	2.66	3 1238
New Orleans, La...	8- 3-02	3.01	1 1014	Memphis, Tenn...	5-26-02	2.64	3 1230
Lincoln, Neb...	5-28-05	3.00	6 1020	Omaha, Neb...	8-26-03	2.63	5 1235
Kansas City, Mo...	8-15-03	3.00	7 1027	Huron, S. D...	8-18-04	2.63	2 1240
Oklahoma City				New Orleans, La...	3-19-05	2.63	1 1241
Oklahoma City	5-23-03	3.00	4 1031	Nashville, Tenn...	9-14-01	2.61	2 1243
Springfield, Ill...	5- 5-01	3.00	6 1037	Lincoln, Neb...	9-14-06	2.61	6 1249
Denver, Colo...	6- 2-00	3.00	1 1038	Lincoln, Neb...	8- 7-07	2.60	6 1255
Evansville, Ind...	9- 2-04	3.00	4 1042	Omaha, Neb...	6-16-00	2.60	5 1260
Ft. Worth, Tex...	6-24-03	3.00	3 1045	Springfield, Mo...	8- 7-06	2.60	10 1270
Memphis, Tenn...	6-23-99	2.99	3 1048	Cairo, Ill...	7-30-01	2.60	3 1273
Evansville, Ind...	7-10-05	2.98	4 1052	Cairo, Ill...	6-22-97	2.58	3 1276
Yankton, S. D...	9-20-02	2.98	3 1055	Evansville, Ind...	5-31-07	2.58	4 1280
Hannibal, Mo...	7- 4-99	2.98	5 1060	Des Moines, Ia...	5-21-03	2.56	5 1285
Des Moines, Ia...	7-18-04	2.97	5 1065	Milwaukee, Wis...	6-12-99	2.55	2 1287
Topeka, Kans...	7-31-02	2.87	7 1072	St. Paul, Minn...	6-12-99	2.54	2 1289
Ft. Worth, Tex...	9-21-00	2.96	3 1075	Indianapolis, Ind...	6- 4-06	2.54	2 1291
Kansas City, Mo...	7-14-07	2.96	7 1082	Oklahoma City			
New Orleans, La...	8- 3-98	2.95	1 1083	Oklahoma City	8-11-02	2.52	4 1295
Hannibal, Mo...	8- 8-99	2.93	5 1088	Topeka, Kans...	8- 4-06	2.52	7 1302
Omaha, Neb...	7-15-00	2.92	5 1093	Huron, S. D...	8- 4-00	2.51	2 1304
Kansas City, Mo...	9- 9-03	2.92	7 1100	Springfield, Ill...	8- 3-05	2.50	6 1310
Memphis, Tenn...	8-30-97	2.92	3 1103	Columbia, Mo...	7-18-02	2.50	5 1315
Cairo, Ill...	6- 7-00	2.92	3 1106	Dodge City, Kan...	5-13-98	2.46	3 1318
Bismarck, N. D...	6-16-97	2.92	1 1107	Little Rock, Ark...	9-10-99	2.44	3 1321
New Orleans, La...	7-25-99	2.92	1 1108	Memphis, Tenn...	3-26-02	2.44	3 1324
New Orleans, La...	7- 7-98	2.90	1 1109	New Orleans, La...	9- 9-98	2.43	1 1325
New Orleans, La...	8- 5-98	2.90	1 1110	Huron, S. D...	5- 9-05	2.41	2 1327
Indianapolis, Ind...	5-29-00	2.90	2 1112	Ft. Worth, Tex...	8-11-06	2.40	3 1330
Louisville, Ky...	3-16-98	2.90	2 1114	Oklahoma City			
Chicago, Ill...	7- 9-03	2.90	2 1116	Oklahoma City	8-12-01	2.38	4 1334
Evansville, Ind...	5-30-00	2.90	4 1120	Ft. Smith, Ark...	9- 2-06	2.38	7 1341
St. Paul, Minn...	10- 3-00	2.90	2 1122	Columbia, Mo...	8-15-00	2.31	1 1342
Memphis, Tenn...	8-18-01	2.88	3 1125	New Orleans, La...	7- 5-02	2.30	1 1343
Chicago, Ill...	5-24-02	2.87	2 1127	Kansas City, Mo...	7- 5-04	2.22	7 1350
New Orleans, La...	7-18-00	2.86	1 1128	Oklahoma City			
Hannibal, Mo...	8- 8-99	2.86	1 1129	Oklahoma City	7-20-97	2.16	4 1354
Cincinnati, O...	7-21-03	2.85	1 1130	Little Rock, Ark...	12-13-01	2.10	3 1357
Kansas City, Mo...	7- 2-05	2.84	7 1137	Kansas City, Mo...	7- 7-02	1.94	7 1364
Louisville, Ky...	6-15-02	2.83	2 1139	Des Moines, Ia...	7-23-00	1.90	5 1369
Ft. Worth, Tex...	10-21-00	2.82	3 1142	New Orleans, La...	4-25-07	1.90	1 1370
Springfield, Ill...	6- 1-02	2.82	6 1148	Lincoln, Neb...	5-24-03	1.81	6 1376
New Orleans, La...	7-17-97	2.81	1 1149	Lincoln, Neb...	9-16-06	1.79	6 1382
Lincoln, Neb...	7-22-02	2.80	6 1155	Hannibal, Mo...	8-10-99	1.73	5 1387
Lincoln, Neb...	5-10-05	2.80	6 1161	Columbia, Mo...	6- 7-98	1.66	5 1392
Little Rock, Ark...	6- 1-98	2.80	3 1164				

Table VI.

Cities.	Years considered.	Years of Dist. record.	Final wght.	Cities.	Years considered.	Years of Dist. record.	Final wght.
Kansas City, Mo...	10	10	7	Hannibal, Mo...	10	9½	5 5
Topeka, Kans...	10	8½	6 7	Columbia, Mo...	10	10	5 5
Wichita, Kans...	10	5	5 10	Springfield, Mo...	10	5	5 10
Lincoln, Neb...	10	11	5 6	Oklahoma City			
Omaha, Neb...	10	11	5 5	Oklahoma City	10	10½	4 4
Des Moines, Ia...	10	11	5 6	Davenport, Ia...	10	6	4 7

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Cities.	Years considered.	Years of record.	Dist. wght.	Final wght.	Cities.	Years considered.	Years of record.	Dist. wght.	Final wght.
Springfield, Ill....	10	6½	4	6	Chicago, Ill.....	10	11	2	2
St. Louis, Mo....	10	11	4	4	Indianapolis, Ind..	10	11	2	2
Ft. Smith, Ark....	10	6	4	7	Louisville, Ky....	10	11	2	2
Dodge City, Kans..	10	11	3	3	Nashville, Tenn....	10	11	2	2
Yankton, S. D....	10	10½	3	3	Shreveport, La....	10	5½	2	4
La Crosse, Wis....	10	6	3	5	Pueblo, Colo.....	10	8	1	1
Dubuque, Ia.....	10	5½	3	5	Denver, Colo.....	10	11	1	1
Evansville, Ind....	10	8	3	4	Bismarck, N. D..	10	11	1	1
Cairo, Ill.....	10	10½	3	3	Columbus, O.....	10	10½	1	1
Memphis, Tenn....	10	11	3	3	Cincinnati, O.....	10	11	1	1
Little Rock, Ark..	10	11	3	3	Lexington, Ky....	10	9	1	1
Ft. worth, Tex....	10	7½	2	3	New Orleans, La..	10	11	1	1
Valentine, Neb....	10	6	2	3					
Huron, S. D.....	10	10	2	2	Total final weight.....				149
St. Paul, Minn....	10	11	2	2	Twice the final weight.....				298
Milwaukee, Wis....	10	11	2	2	Five times the final weight.....				745

Table VII. Precipitations Used in Determining Form of 40 Min. Typical Rain Curve, Giving Depth in Inches for Each 5 Minutes, From the Beginning of the Downpour.

No.	Cities—	Date	Five Minute Intervals.									
1	Evansville, Ind.	9-2-00	.08	.09	.09	.17	.26	.32	.28	.21	.15	.21
2	Lexington, Ky.	8-22-00	.22	.21	.25	.28	.36	.21	.13	.15	.05	.20
3	Columbia Mo.	8-22-05	.04	.08	.06	.20	.34	.42	.36	.24	.12	.06
4	Shreveport, La.	6-1-06	.08	.20	.31	.39	.17	.22	.20	.16	.11	.05
5	New Orleans, La.	3-14-03	.07	.32	.35	.25	.17	.13	.10	.29	.07	.24
6	Springfield, Mo.	7-26-05	.07	.14	.20	.32	.43	.26	.34	.17	.06	.08
												.29
												.12
												.10
												.04

Table VIII. The Same as the Above, Except that the Arrangement is Symmetrical, as Shown in Fig. 5.

No.	Cities—	Five Minute Intervals.									
1	Evansville	.08	.09	.09	.17	.26	.32	.28	.21	.15	.21
2	Lexington		.22	.21	.25	.28	.36	.21	.13	.15	.05
3	Columbia		.06	.06	.20	.34	.42	.36	.24	.12	.06
4	Shreveport		.08	.20	.31	.39	.17	.22	.20	.11	.05
5	New Orleans	.07	.32	.35	.25	.17	.13	.10	.29	.07	.24
6	Springfield		.07	.14	.20	.32	.43	.26	.34	.17	.06
											.29
											.12
											.10
											.04

Table IX. Showing Method of Obtaining Typical Intensities. The Data are those of Table VII, Multiplied by the Weights Given.

No.	Weight	Weighted Five Minute Intervals.									
1	4	.32	.36	.36	.68	1.04	1.28	1.12	.84	.60	.84
2	1	.22	.21	.25	.28	.36	.21	.13	.15	.05	.20
3	5	.20	.40	.30	1.00	1.70	2.10	1.80	1.20	.75	.25
4	4	.32	.80	1.24	1.56	.68	.88	.80	.64	.44	.40
5	1	.25	.17	.13	.10	.29	.07	.24	.22	.32	.20
6	5	.35	.70	1.00	1.60	2.15	1.30	1.70	.85	.30	.40
											.60
											.110
											.50
											.20
Total	.20	.07	.32	.87	1.58	2.06	3.86	5.96	7.74	5.18	4.99
Average		.00	.01	.04	.08	.10	.19	.30	.39	.26	.25
Hourly rate		.00	.12	.48	.96	1.20	2.28	3.60	4.68	3.12	3.00
										2.04	1.44
										1.32	1.32
										.84	.36

## DISCUSSION.

*Mr. C. D. Hill, M. W. S. E.:* As a preliminary I will ask Mr. Balcomb one or two questions.

In the paragraph below Fig. 2 are given three average rainfalls, 2.62, 3.26 and 3.42. I do not quite understand what they refer to. Are these all 40 minute curves?

*Mr. Balcomb:* No; they are 40, 20, and 10 minute curves.

*Mr. Hill:* Were they the average rainfalls of Kansas City for those periods of time?

*Mr. Balcomb:* No, they were rainfalls over the whole Mississippi Valley.

*Mr. Hill:* But weighted for value, for use in Kansas City?

*Mr. Balcomb:* Yes, for use in Kansas City.

*Mr. Hill:* So that in designing the sewers in Kansas City, you used those rainfalls for those periods?

*Mr. Balcomb:* Yes, 2.62 in. for 40 minutes, 3.26 in. for 20 minutes, and 3.42 in. for 10 minutes. That is, that rate of rainfall per hour; there was not that much flow per hour.

*Mr. Hill:* In designing the sewers of those different lengths you used those three different rates of rainfall?

*Mr. Balcomb:* That is the idea. The first one is a value which would make the sewers flooded every ten years; the second, every five years; the third, every two years.

*Mr. Hill:* The author is to be highly complimented for doing such painstaking work in solving the problem for Kansas City, and incidentally in giving information to all of us in the whole Mississippi Valley. Work of this sort is real work and enormous work that aids the profession greatly. I have often wished I could do it, myself, but we are too busy building sewers to plan them intelligently.

Without wishing to criticize the paper, I will point out some differences, to guard against drawing false conclusions and applying them elsewhere. This study was made in Kansas City, principally for Kansas City or for cities of that type. Chicago is a larger city, and a very flat one. The conditions here are different—even our rainfall is different—so some of the conclusions of Mr. Balcomb could not very well be applied here.

Let me ask, Mr. Balcomb, in regard to this study of storm-water drains, is it applied to combination sewers or merely to storm drains or both?

*Mr. Balcomb:* Strictly speaking, the study would apply only to storm drains. The fact that sanitary sewage forms only about 1% of the flow, as a rough average, makes it fairly applicable to a combined system. It is not at all applicable to a sanitary system only.

*Mr. Hill:* The reason I asked the question is this: In Kansas City, where it is hilly and where there is natural drainage, it is good practice to carry storm water in the street gutters, as

much as possible, and where there is a double system—the storm water carried through drains and the sewage through sanitary sewers and the two divorced—I believe it is good practice to design storm drains somewhat smaller than if they were combined, because if they are surcharged the damage done is principally in the street, as the water may be held back in the gutters and may flood the pavement, but filthy sewage is not backed up into the basements as it is in Chicago when we have rains exceeding certain amounts. So, from that standpoint, there is quite a difference—whether one is designing a storm-water drain or a combined sewer and drain. In Chicago, of course, we cannot carry water a block or two along the gutters. We can let it stand a block or two along the gutters and sometimes do, but that is as far as we can go and it is not good practice. As we pave our streets—lay new impervious pavements—we increase the number of catch basins and make the run shorter, and that instantly increases the duty on the sewers and increases the chance of back water in the basements.

The general problem of computing the runoff from rain storms, I think, is the most fascinating one in engineering. It is equal to the old problem of squaring the circle and inventing perpetual motion, one can always work at it and never quite complete it. The method proposed by the author is, I think, very scientific, so far as I can see, but I am free to say that I do not fully understand it as to the details. It follows—in a way—the method used by Mr. Grunsky, as stated by the author. The idea is this: If it is desired to determine how much water will flow through a sewer at any point that drains a certain area, there will be a certain storm of maximum intensity that should just fill that sewer. If the sewer is correctly designed there should be some storm of maximum intensity which will just fill it, and when it has passed by the water will run out and there is no damage done. It is the ideal solution. The sewer will not be full until the water has been brought from the farthest point in the district. The time taken for the water to come to this point from the distant point, is the time length of the sewer, the time of concentration. At the same time the sewers will have become filled. There will be a certain amount of storage in the sewers. That point, so far as I know, was original with Mr. Grunsky. I am not certain that Mr. Balcomb uses that element in the computation, but I believe it is really an important element. Mr. Grunsky demonstrated mathematically—that is, I think he did—certain things in that connection. I could not figure it out that way, but I did this: I designed a typical system of sewers and estimated approximately the size of the sewers to drain this territory—estimated the cubic contents—and I came to the conclusion that the time of filling those sewers would be approximately the same as the time of flow from the farthest point to

the point in question—in some cases the time was more and in some it was less—but taking an average, I came to the conclusion that if one had the time of flow from the farthest point to the point in question he would have approximately one-half the time of concentration. That is one element—the time of the maximum rainfall. The other element is the amount of rain that will fall in that time. As I do not quite understand Mr. Balcomb's method, I have gotten at the matter in another way. A few years ago Professor Talbot published a diagram or a formula for the annual rainfall in terms of the time. That is, we frequently have an intense rainfall; it may last merely five minutes, or it may last for an hour or two and during some five minutes of that time the rainfall will be intense. We get a greater intensity for a certain period of five minutes than for any period of ten minutes; we get a greater intensity for a certain period of ten minutes than for any period of twenty minutes, and so on. That is indicated in this paper by Mr. Balcomb, and can be expressed in any locality by a curve, although Professor Talbot expressed it by a formula. Intensity of rainfall equals 105 divided by time in minutes plus 15. A few years ago I plotted that on a chart and then plotted the intensity of the rainfall from various rains here in Chicago. Altogether it covers twenty years, but not all the storms of twenty years. The basis of that tabulation was a paper published by this Society some ten years ago by Mr. Duryea on the subject of precipitation of rainfalls in Chicago. I used that information and then from time to time, whenever there has been an exceptionally severe storm, I have obtained the data from the local office and find that there have been very few storms—perhaps three—that have exceeded the rate given by that formula—that is, in the ten-minute period. In the twenty-minute period I have plotted two, in the thirty-minute period, three, in the sixty-minute period, two. So, if one will increase the rate, take the intensity of rainfall at 120, divided by the time plus 15, he will include nearly every severe storm in Chicago.

If I were working out the problem in this manner, I would simply take this curve. If I determined that the time of concentration of a certain sewer was thirty minutes—that it would take thirty minutes for the maximum runoff to accumulate—I would look up the maximum rainfall to be expected in thirty minutes and multiply it by the area—provided the area was entirely impervious—where we were going to get the entire rainfall. That is, as I understand, practically what Mr. Balcomb has done, only in a little different way.

As to the merits of the method, I believe it is the proper one to use where we have really an impervious surface, or where the surface is so impervious that it can be fairly estimated, or where it is comparatively small so that we can estimate the time quite closely; but in dealing with a large district with varying degrees

of permeability, the condition is different. Unless the district is entirely paved and roofed, one portion of the water will not start as soon as another; that is, there will be a quick runoff from the roofs and a quick runoff from the pavement, and we may get a maximum intensity from that source before there is much effect from the remainder, but there will be some effect from the remainder and the larger the district the more effect will be obtained from the so-called pervious area. We will begin to get water from the ground after the water has run off from the pavement near by, but while we are getting the water from the roofs from the distant area, we keep getting the slowest portion of the water near by, and will not get the water from the ground in the pervious area in the distant district until after this maximum runoff occurs, and then it does not matter. When there is a large area that is not entirely paved we have a very indeterminate problem, and I doubt whether that method would give fairly correct results. That is, I believe it would give too large results. We would be on the safe side unless we were guessing too low as to the amount of the impervious area.

It would be very interesting if Mr. Balcomb would give us information, when his paper is published in permanent form, as to some of the typical districts, the actual area, and approximately the impervious area, and the results obtained from this method, so that we could compare his results with other methods. For instance, a good many years ago Mr. McMath, in St. Louis, had the same problem, but he worked it out in another way; he took an old formula and secured the facts and established his coefficient. In the light of our present knowledge, I am not certain that it is not a good way to do—get some facts and make the formula fit the facts, and then apply the formula; that is, for these large districts where the conditions are uncertain. It would be still more interesting if we could know the actual results from the sewers Mr. McMath designed according to this method so many years ago. We frequently hear, as we have tonight, about methods used in designing sewers, but we seldom hear about them afterwards, and that is the real test.

Perhaps I might interject right here that some of the sewers in Chicago were planned over fifty years ago by Mr. Chesbrough, and in his report at that time he said that they were sufficient, in his judgment, to care for the runoff of one inch rainfall in an hour. I think it is a fact that the sewers across the river—where the district is well built up—are very full when there is a rainfall of nearly an inch an hour. I think Mr. Chesbrough made a good guess, and he had a worse formula than that of Mr. McMath. Mr. Chesbrough, by the way, predicted that the time would come when the population would increase so that we would have to supplement the sewers planned by him by an additional set. He proposed one sewer in every second street and

they were so built. He said that eventually the city would need a similar sewer in every street. We have not yet built them, though I admit we need them.

In regard to construction, again there is a difference between Kansas City and Chicago. The best construction in Kansas City might not be the best in Chicago, and vice versa. I cannot admit that concrete is better than brick, neither will I admit that brick is better than concrete; so far as I know, it is a standoff. We are using both, and I am not ready to say which is the better in any way. I may make up my mind after a few years, but it certainly is not apparent at present that one is better than the other, either in economy or efficiency. We get no smoother sewers made of concrete than we do of brick, and I am sure they are not more durable. We have brick sewers fifty or sixty years old which are just as good as when they were built. Our grades are flat, there is no high velocity flow in the sewers, so there is no chance to wear them out and there is no question as to their durability. As to the matter of economy, it is largely a question of local conditions—of the class of men we get to build them. It is difficult to build a concrete sewer as fast as a brick sewer can be built; we can put in as many brick masons as we desire. I have seen 200 ft. of brick sewer built in a day, day after day. As a matter of fact, we have built a concrete sewer 8½ ft. in diameter, and averaged 100 ft. a day for every working day for three months. We cannot build a concrete sewer at that speed and have it look like a pipe which is shown as the sample by the manufacturer. It is hardly as smooth as brick, but it is strong and it is cheap when built at that speed.

In regard to contracts. In any form of contract I think it is a great mistake to work for the ideal. I believe we want to work toward commercial accomplishment; we want to specify what we can get and then get it. A few years ago we were revising our specifications, as it became necessary to have some more printed. I asked four of the sewer contractors to join me in looking over the specifications to see if there was anything to which they objected, or anything that should be changed. To my surprise they really wanted the best things to remain in the specifications. When we had completed our work we had specifications that could be carried out, there was nothing in them unreasonable; nothing that contractors were not willing to do; nothing impossible to do; nothing impracticable. The result will be a good commercial job—not the finest or best that could possibly be done, but we will get the most value for the money paid.

In regard to extras, there should not be any. If an engineer really understands his business and has the time to study the problem in advance, he ought to foresee what is going to be done. Of course some things are likely to occur that cannot be fore-

seen, but most things can be provided for tentatively. We can provide a price per unit of material or work; if it is necessary to leave in the lumber, braces, or anything of that sort provide a price for the lumber per unit of measurement; provide a price per unit for any extra brick-work or concrete that may be necessary. It is possible to provide for almost all contingencies so that when we get through there will be little opportunity for extras.

*Mr. L. K. Sherman, M. W. S. E.:* The relation between rainfall and runoff is quite complex. Mr. Alvord, in a paper before this Society, stated some fourteen different points governing runoff. The runoff in the valley of the Kankakee River is only 23% of the rainfall.

Mr. Balcomb has given in his paper, I think, the logical and rational method for arriving at the chief point of the fourteen points that govern runoff,—that is, the rainfall,—but he has covered only the one point. There are other points aside from perviousness that should be considered, and it is my opinion that the measured observation of the runoff, used comparatively, is more certain in designing storm-water sewers than any observations on the rainfall. I am not criticizing the great value of that, and I realize that in comparatively small areas the relation between rainfall and runoff is more direct than in the large drainage-areas with which I have had mainly to do. But in the large drainage-areas where I have had occasion to compare the runoff with the storms at different periods, I could observe very little relation between the runoff and the downpour of the storms.

Mr. Balcomb suggested that it was advisable to make sewers as impervious as possible to subsoil drainage. I think there are two sides to that question, and that a sewer is valuable in draining the subsoil. This especially applies to the vicinity of Chicago, and in some cases the more the sewer leaks, the better the sewer is as a drain for the subsoil.

*Mr. Wm. M. McCartney, M. W. S. E.:* My experience has been chiefly along the line of measurement of runoff or flood water and I have not made any special comparison as between that runoff and the rainfall in any particular case.

I have seen the after-effects of one or two heavy rain-storms that were in the nature of water spouts. The overflow of Hickory Creek in Joliet, in 1902, was one instance. Quite a serious amount of damage was done there through that rain-storm. It flooded not only Hickory Creek and vicinity, but a considerable portion of Joliet as well, the water standing quite high in the Santa Fe railroad station there. So far as the sewers at Joliet were concerned, they were of course absolutely inadequate to take care of any such flow. That was on the order of one of those ten-year periods mentioned by Mr. Balcomb, I imagine; it

may have been a longer period for Joliet. At any rate, it is on the order of that rainfall for which one would not expect to provide in designing a sewer system.

*Mr. H. W. Deberard, M. W. S. E.:* In connection with investigations for the Metropolitan Sewerage Commission of New York, of various systems in the five boroughs of greater New York and other municipalities in New Jersey within a radius of about 20 miles from the City Hall, there was found every conceivable kind of construction, design, and allowance for runoff. It is now several years since the consolidation of the several boroughs, but there is a different method of design in each one, as may be noted from the following table which has been compiled by the engineering department of the Board of Estimate, and is given here as an example of how much variety of procedure there is in this question of calculating the size of sewers even in the same general locality.

PLACE.	RUNOFF FORMULA.	MAX. RAINFALL PROVIDED FOR.
Manhattan	Hering's	2 in. per hour
Brooklyn	McMath's	3 in. per hour for 30 min.
The Bronx	Rational: $Q=C I A^*$	$I=120 \div (T+30)$
Queens	Rational: additive	$I=\frac{725 T - 299.85}{T(T+4.14)} \ddagger$
Richmond	Rational: $Q=C I A^*$	$I=\frac{105}{I+25} \ddagger$

\* $Q$ =Cubic feet per second.  $C$ =Per cent of imperviousness.  $I$ =Intensity of rainfall in inches per hour.  $A$ =Area drained in acres.

†Following a 10 min. rainfall at the rate of 3 in. per hour.

‡Following a 5 min. rainfall at the rate of 3.5 in. per hour.

As has often been pointed out with regard to river data, the only way to calculate runoff is to measure it. It may be opportune to say that the city of St. Louis has recently equipped the sewers in a 520-acre typical district with recording gauges and installed a number of standard and tipping-bucket rain gauges. The information thus obtained will be used as the basis for the establishment of a formula to be used locally.

#### CLOSURE.

*Mr. Balcomb:* I agree with Mr. Hill that the method as worked out in detail for Kansas City is not applicable to any other city, but the principles are applicable, and it becomes necessary simply to work out the details, in accordance with these principles, for a given city. It is true, also, that the method gives correct results in proportion to the smallness of the areas considered. The effort, with the different formulae, is to make them blanket propositions so as to cover any area; but the conditions vary so much, as Mr. Hill has well pointed out,

with regard to slope imperviousness, and local conditions, that at best they are only approximations. That they are good approximations is the best we can say. The smaller the area taken, the nearer correct the results.

I like his attitude in conferring with contractors regarding specifications. I have done likewise and been well satisfied with the results obtained. I find that contractors generally, not only know good specifications but, if you interpret them fairly, they are glad to work under such specifications. I would certainly commend the practice to progressive cities.

Referring to Mr. Grunsky's solution and the use of sewers for storage, like Mr. Hill I worked over the method very carefully, but failed to see much force in the thought, because at the instant the sewers are filled to their utmost capacity and are flowing at the resulting rate, we have already allowed for their storage-capacity in computing the time at which this condition would be reached; also their cubic contents compared with their carrying capacity is so small as to affect the problem but slightly.

With reference to Mr. Sherman's statement, that the paper covers only the main feature of the problem his point is well taken. The fact is, the main point is as far as we have reached in Kansas City. It is the one investigation for which the money was available, and we have tried to make it thorough. In regard to the other points, there are a number of weir stations planned for the different creeks that now carry runoff in the new territory, and also gauging stations with automatic records for a number of sewers in different parts of the older portions of the city. Three automatic rain-gauge stations have already been established, to supplement the weather bureau, so that we may know whether the rainfall is the same over the different parts of the city. I agree with him that just as fast as data can be gathered, they should supplement what we already have, in order to work out the method definitely to a satisfactory conclusion.

# HEAT TREATMENT OF HIGH-SPEED TOOLS

RELATION BETWEEN TEMPERATURE AND LIFE OF TOOLS.

C. P. Berg, M. W. S. E.

*Presented June 15, 1910.*

1. The experiments described in this paper were undertaken in order to obtain the relation between temperature in tempering and the life of tools to a greater degree of exactness than heretofore known to the writer.

2. The perfection of the electric furnace for high temperatures and development of same into dimensions for such practical purposes as heat treatment of metal-cutting tools, in connection with the electric pyrometer for measuring these high temperatures, has made possible such investigations as stated above.

3. The writer will confine himself exclusively to the attempt of solving the problem as it concerns the effect of various temperatures upon the life of high-speed tools, or the comparative values of the same.

4. Although the carbon steels are of decidedly earlier origin and have been experimented upon by several investigators, it is the hope of the writer to attempt an addition to the present available information in the near future.

5. Most notable of recent scientific work in this line is the paper presented by Mr. George W. Sargent, Ph. D., at the meeting of the Franklin Institute, June 3, 1909: "Some remarks upon the critical points of steel, their method of determination and the value of same," in which he records a series of experiments made at the Carpenter Steel Works.

While the heat treatments and various tests described in his paper were conducted in a thoroughly scientific manner, Mr. Sargent failed to show the value of his investigations on the *life* of metal-cutting tools.

6. Fully appreciating the value of specialists for the various tests required to complete this work, the writer has been fortunate in being associated with, and assisted by, professional experts during the entire experimenting period, each one carrying on his special part of the investigation.

7. The writer would particularly mention Messrs. W. C. Post, A. D. de Pierrefeu and J. H. Critchett of the Chicago Metallurgical Laboratory in connection with the metallurgical examination by photomicrographs, Mr. James Lawrie, Ph. D., with the hardness test, and Mr. W. V. Young of the Hoskins Mfg. Co. He would also

acknowledge his indebtedness to the Hoskins Mfg. Co. for enabling him to carry on the heat treatments at their Chicago demonstrating plant, and the Link-Belt Company, at which shops the cutting tests were performed.

8. To recapitulate: The writer's work may be said to consist of:

A. To establish a guide as to how rapidly the steel should be heated under the high heat treatment by a heat absorption test.

B. To determine at which degree of temperature in the heat treatment, the maximum cutting efficiency occurs for a steel of a certain chemical composition.

C. To give the reasons for the relations found by these tests by metallurgical examinations and to illustrate the same by photomicrographs.

#### STEELS USED IN TEST.

9. Four prominent high-speed steels were selected to be experimented upon. These steels were marked A, B, C, and D, and these marks will be retained in referring to the four series of specimens undergoing the various tests.

The chemical analyses of these steels are as shown in Table 1.

TABLE 1.

		A	B	C	D
Carbon	C.	.70	.56	.74	.67
Silicon	Si.	.211	.248	.262	.278
Sulphur	S.	.016	.035	.016	.010
Phosphorus	P.	.010	.012	.016	.015
Manganese	Mn.	.27	.20	.21	.22
Chromium	Cr.	4.76	5.54	5.80	3.30
Tungsten	W.	15.15	8.45	10.94	15.57
Nitrogen	N.	.005	.005	.004	.015

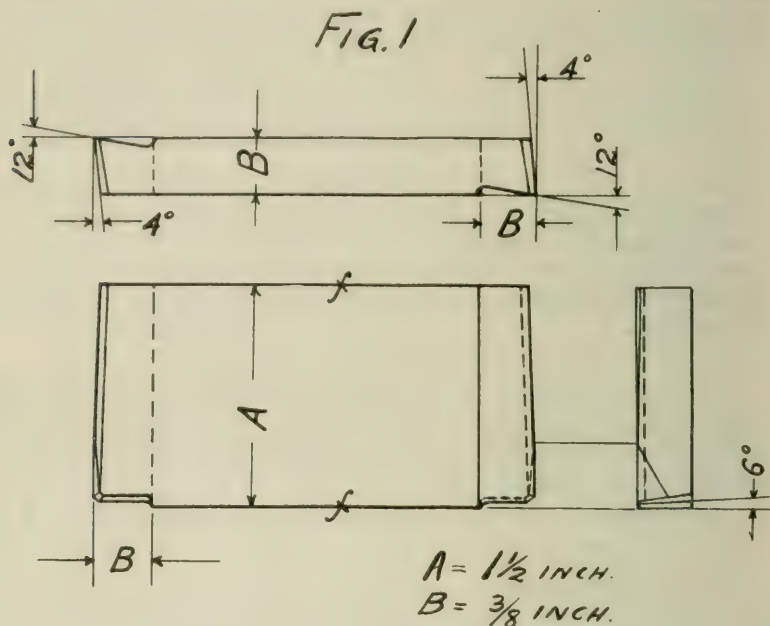
Chemical Composition of Steels.

#### TOOLS USED IN TEST.

10. In order to eliminate the effect of forging upon the steels to be tested, straight tools for boring or inside turning, ground to shape and to standard angles in a grinder, were decided upon.

Steel bars of  $\frac{3}{8}$  in. by  $1\frac{1}{2}$  in. size were cut off from the four previously mentioned steels, to be made into tools for roughing cuts in boring cylinders to  $4\frac{1}{2}$  in. diameter. The tools were treated

and ground with a cutting edge on both ends and to cutting angles as shown in the accompanying sketch, Fig. 1.



Boring Tool Used in Tests.

#### SPECIMENS USED FOR PHYSICAL TESTS.

11. Cylinders made from cast iron of a chemical composition producing exceptionally hard castings, were provided for this test.

In order to insure equality, the greatest care was taken in preparing the molds for these castings, and all were poured from the same heat.

12. In view of the fact that the life of a tool decreases with the increase of combined carbon in the castings on which it is used, and again that the amount of combined carbon is dependent upon the rapidity with which the cast iron is cooled after pouring it into the mold, it became necessary to find some method by which these castings could be cooled in the same length of time.

13. The molds were therefore specially arranged for this purpose, and eight minutes after the iron was poured the cores were removed and the castings cooled in water. This gave the castings as nearly as possible the same amount of combined carbon.

14. Dimensions of the cylinders were as follows: Outside

diameter, 8 inches; length, 8 inches; and diameter of core, 4 inches, leaving  $\frac{1}{2}$  inch of metal to be removed by the double end tools to be tested, or, in other words, providing for  $\frac{1}{4}$ -inch depth of cut for each end of the tool.

15. The thickness of metal or walls of the cylinders being 2 inches, the castings were inspected for soundness and then considered if of a quality for the test or condemned.

#### HEAT TREATMENT OF THE TOOLS.

16. The temperatures used in the heat treatment of tools have heretofore generally been measured in practice by the terms: cherry red, bright yellow, white, etc. These measurements of heat were probably as correct as any other in connection with the old-time method of tempering tools in the blacksmith forge, where no accurate control of the heat could be obtained.

17. Admitting that there are experts in this line, who are able to guess temperatures very closely by the color of the heated steel, the writer has heard differences of opinion, when the limit line was to be drawn between white and bright yellow, etc.

18. With the modern electric furnace, its perfect control, evenly distributed heat, reducing atmosphere preventing burning of the steel, and the thermo-electric pyrometer for measuring temperatures, the science of treating metal-cutting tools has taken a long step forward.

19. The instruments as used for the experimental tools are shown in the accompanying illustration, Fig. 2, from a photograph. To the left can be seen the muffle furnace used for preheating the steel slowly up to 1,400 deg. Fahr., prior to transferring it to the tube furnace, seen to the right in the picture, there to be subjected to the high heat treatment.

20. The muffle furnace, to the left, is of the wire resistance type constructed for temperatures up to 1,800 deg. Fahr.

21. The tube chamber design of furnace, to the right, where the experimental tools were subjected to the high-heat treatment, is constructed for temperatures up to 2,600 deg. Fahr.

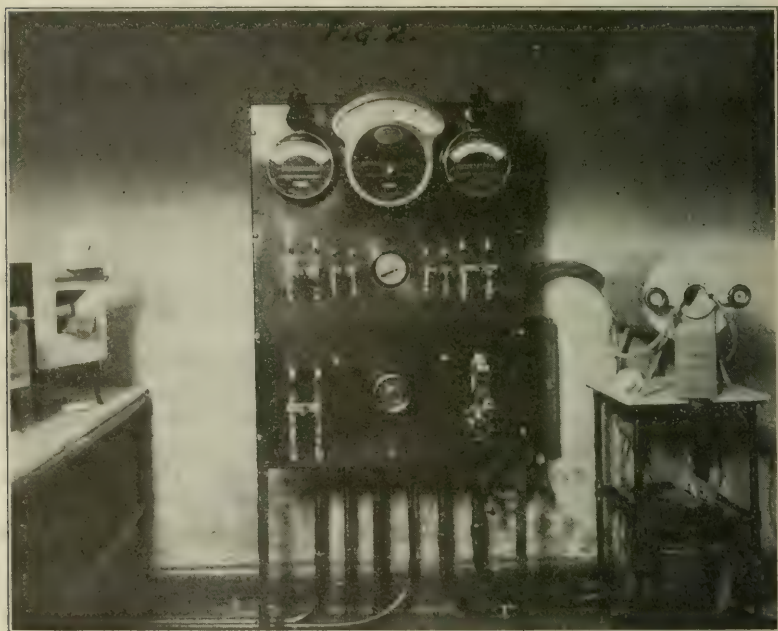
22. The current for both of these furnaces is controlled on the switchboard shown in the center of Fig. 2. The switchboard also carries the thermo-electric pyrometer, which is connected with the thermo-couples by the switch in the center of the board, this rendering possible the reading of temperatures in several furnaces on this one instrument by turning the switch, the contact points of the switch being numbered to avoid confusion. A wiring diagram of the pyrometer and selective switch is shown in Fig. 3.

23. To insure accuracy the thermo-couples used were calibrated before and after the readings made on the temperatures of the test specimens. The calibrating consisted in taking a reading

on water at the boiling point (212 deg. Fahr.), on aluminum at the melting point (1,215 deg. Fahr.), and on copper at the melting point (1,949 deg. Fahr.).

24. In giving high-speed tools the high heat treatment, the temperature should be raised rapidly to the desired degree for quenching, but enough time should be allowed for the heat to penetrate thoroughly to the center of the tool, which otherwise would be in danger of cracking.

25. To do this, it is necessary to know the length of time required by the tool under treatment to absorb the heat to which it is subjected. In order to ascertain this for a guide in treating



Electric Heating Furnaces and Switchboard.

the experimental tools, the heat absorption test was made, from which the results are shown by the diagram in Fig. 4.

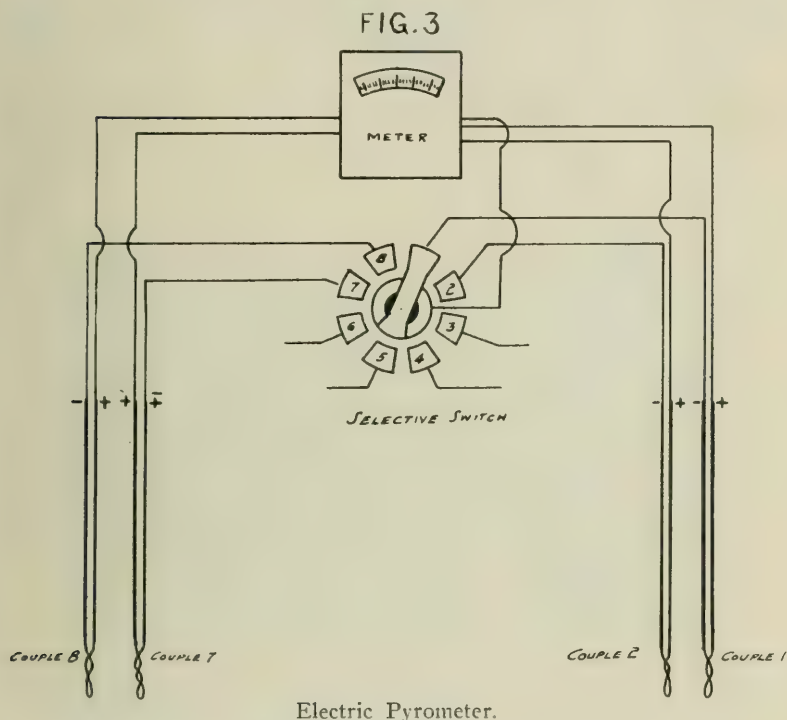
26. Four pieces of steel of equal size,  $\frac{3}{8}$  in. by  $1\frac{1}{2}$  in. by  $1\frac{1}{2}$  in., one from each of A, B, C, and D, were prepared with a hole to receive the end of the thermo-couple, as shown in Fig. 5.

27. The furnace was run up to 2,200 deg. Fahr. and kept at this temperature. The test pieces were placed in the furnace individually and time observations were taken on the increasing temperature of the steel.

28. Noting the uniformity of the curves in the diagram, Fig.

4, it will be seen that the molecular change in the steel up to 2,200 deg. Fahr. did not at any point disturb the evenly increasing temperature of the specimen. As will appear later, it was found that some of these steels are treated with the best results at 2,150 deg. Fahr. The molecular change evidently is not violent enough and quick enough to stop the increase of temperature in the steel, at least it could not be observed by the instruments used.

29. From other tests made on heat absorption with various

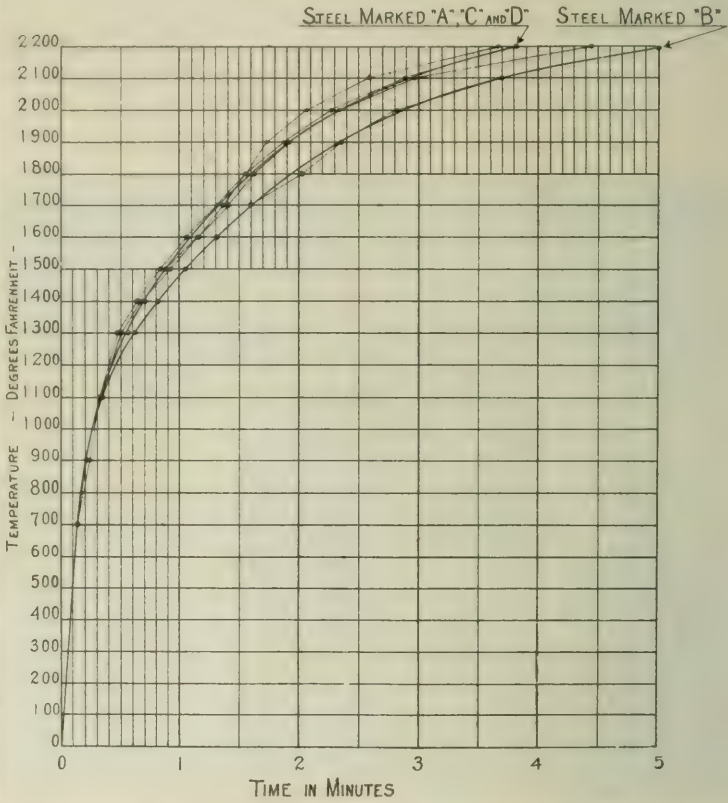


sizes of steel, it appears that the time for the absorption of heat increases very nearly in proportion to the thickness of the steel. Thus, a piece of steel  $\frac{3}{4}$  in. thick requires twice as long a time as is shown by the diagram in Fig. 4, which would be 6.6 minutes for a temperature of 2,150 deg. Fahr. for any one of the A, C and D steels.

30. Plate I shows fractures of specimens from series A, which have been heated to 2,150 deg. Fahr. but which were left in the furnace a certain length of time after reaching this temperature before quenching in oil at 100 deg. Fahr. Comparing these fractures with the ones from the experimental tools and the results

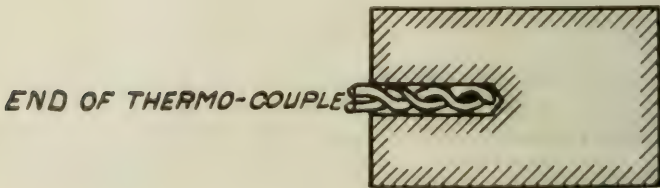
FIG 4

ILLUSTRATION OF HEAT ABSORPTION  
BY THE FOUR STEELS.



The Heat Absorption of Steels.

FIG.5



from the physical tests of the latter, they strongly indicate the necessity of careful observation in the matter of time for the tool to remain in the furnace to become thoroughly and uniformly heated.

31. A hardness test on these specimens performed with a scleroscope gave the results shown in the following table:

TABLE II.

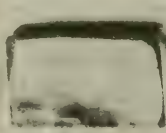
Specimen	Length of time left in furnace.	Hardness by Scleroscope.
1	2 minutes	80
2	4 "	79
3	6 "	78
4	8 "	68
5	10 "	79
6	12 "	70

# PLATE I

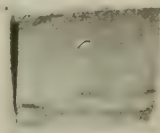
*Fractures from specimens of Series A  
Heated to 2150° Fahr. and the length  
of time for the specimens to remain  
in the furnace varied. Specimens  
quenched in oil at 100° Fahr.*



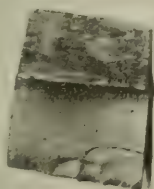
1-Left in furnace  
2.00 Min. before  
quenching



2-Left in furnace  
4.00 Min. before  
quenching



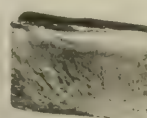
3-Left in furnace  
6.00 Min. before  
quenching



4-Left in furnace  
8.00 Min. before  
quenching.



5-Left in furnace  
10.00 Min. before  
quenching.



6-Left in furnace  
12.00 Min. before  
quenching.

32. Based upon the above results, the heat treatment of the experimental tools was undertaken:

The specimens were marked, preheated to 1,400 deg. Fahr., and from this temperature heated to the various degrees of high heat, as shown in Table III. At the temperatures indicated in the table, the specimens were quenched in oil, which was kept constant at 100 deg. Fahr.

33. For convenient comparison, the results of hardness tests with the scleroscope upon the treated specimens have been shown in Table III.

TABLE III.

Steel Marked	Specimen Marked	Temperature, Fahr. Specimen Quenched	Hardness by Scleroscope
A	1	1850	78
	2	1900	81
	3	1950	76
	4	2000	78
	5	2050	81
	6	2100	82
	7	2150	83
	8	2200	81
	9	2250	77
	10	2250	77
	0	2300	74
B	11	1850	78
	12	1900	74
	13	1950	75
	14	2000	77
	15	2050	83
	16	2100	83
	17	2150	82
	18	2200	79
	19	2250	78
	20	1750	68
C	21	1950	78
	22	2050	80
	23	2100	80
	24	2150	83
	25	2200	80
	26	2250	75
	27	2300	73
	28	2350	..
	29	2325	71
	30	2350	68

D	31	1950	70
	32	2050	75
	33	2100	76
	34	2150	81
	35	2200	79
	36	2250	83
	37	2300	86
	38	2350	86
	39	2300	86
	40	2400	84

34. Specimen 0 of series A softened and caved in on one side.

Specimen 28 of series C softened so the free end (not supported by the tongs) tore off in removing it from the furnace. An illustration of this specimen is shown on Plate VI. Specimen 30 was taken to replace the broken one, and special precautions were made for its removal from the furnace, and it was quenched without mishaps.

35. The specimens receiving the maximum heat all fused at the ends without exception, and some were, as previously stated, considerably softened.

36. In order to get the reading of temperature of the steel itself, a wire loop (wire 3-64 in. diam.) was put around one end of two specimens, which were to receive an equal amount of heat. The loop was made loose enough to permit the moving apart of the two free ends of the specimens. A wedge-formed space was obtained between them, in which the end of the thermo-couple was held firmly, yet from which it could be easily removed.

#### PHYSICAL TESTS.

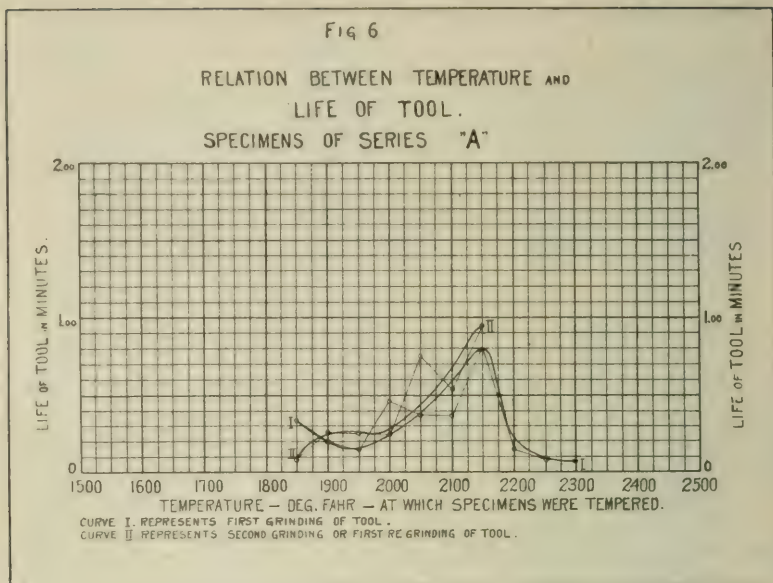
37. The life or durability of these tools, treated in the previously described manner, appears to vary a good deal. Being ground into tools as described in paragraph 10, and shown in Fig. 1, the specimens were put to work under equal conditions on the castings described in paragraphs 11, 12, 13, 14, and 15.

38. A 34-in. vertical boring mill was selected for the test, in order that the chips should clear away from the tool easily. The ends of the cylinders were faced, to eliminate the scraping of this scale by the experimental tools.

39. The results from the test run on the specimens from series A are plotted in the diagram, Fig. 6.

It should be noted that the specimens quenched at a temperature above 2,150 deg. Fahr., failed almost immediately and broke.

40. The second curve (II), which represents the second grinding of the tool, shows a slight increase in durability. This indicates the effect a second heat treatment (drawing the temper of the tool after the high heat treatment) would have upon the tool, which effect can be gotten as readily by running the tool at high cutting



"A" Steels—Temperature and Life.

speeds until it fails, and have it reground, as by drawing the temper in the furnace. However, this method is less accurate, as there is no means of determining the heat thus developed under the cutting action, at the present time.

41. The cutting speed, 80 feet per minute, the thickness of the shaving or feed per revolution, 0.0339 inch, and depth of cut,  $\frac{1}{4}$  inch, at each end of the tool, were kept constant for all specimens and for both grindings.

42. Results from the test run on the specimens of series B are plotted in the diagram, Fig. 7.

The curves here do not present a great deal of uniformity at the low temperatures, but improve and become more distinct as the temperature increases.

43. The specimen receiving the highest heat showed the maximum durability, but it failed very suddenly and broke into several pieces. The fractures gave evidence of brittleness.

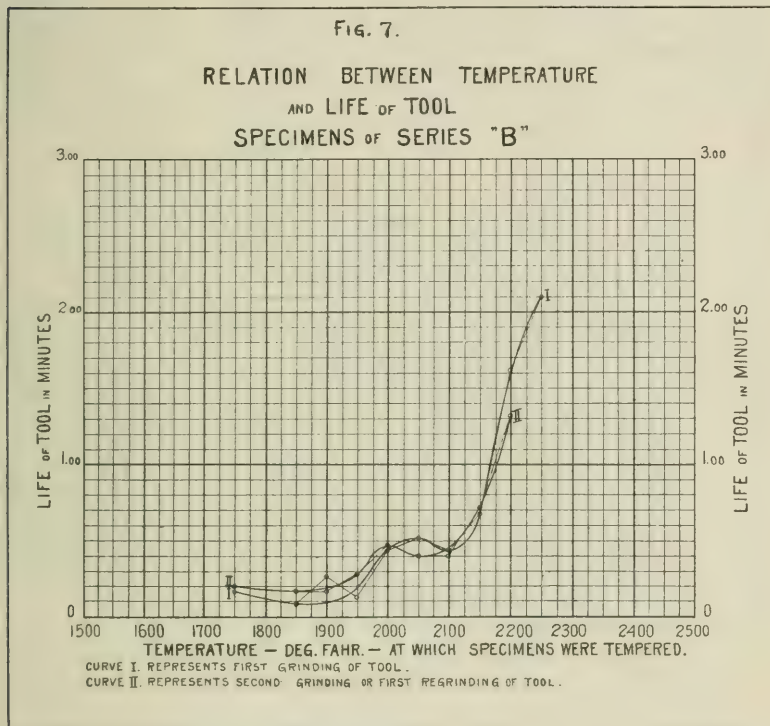
44. Practically no difference in durability appears between the first and second grinding of the tool.

45. The cutting speed, 80 feet per minute, the thickness of the shaving or feed per revolution, 0.0339 inch, and depth of cut,  $\frac{1}{4}$  inch at each end of the tool, were kept constant for all specimens and for both grindings.

46. The results from the tests run on the specimens of series C are found plotted in the diagram, Fig. 8.

The cutting speeds were evidently too high for this grade of steel. The durability being very low at all points, the variations are not distinct. However, it will be seen that the durability attains its maximum at 2,150 deg. Fahr. in Curve I, representing the first grinding of the tool. The dotted lines show that the specimen which was quenched at 2,300 deg. Fahr., failed and broke almost immediately after starting.

47. Curve II, representing the second grinding of the tool, does not show any variations whatever, and the difference between



"B" Steels—Temperature and Life.

this and first grinding is negative. Both these occurrences are directly due to an increase in cutting speed of 20 feet per minute for the specimens on second grinding.

48. The cutting speed, 80 feet per minute, for first grinding, and 100 feet per minute for second grinding, the thickness of shaving or feed per revolution, 0.0339 inch, and depth of cut,  $\frac{1}{4}$  inch at each end of the tool, were kept constant for all specimens.

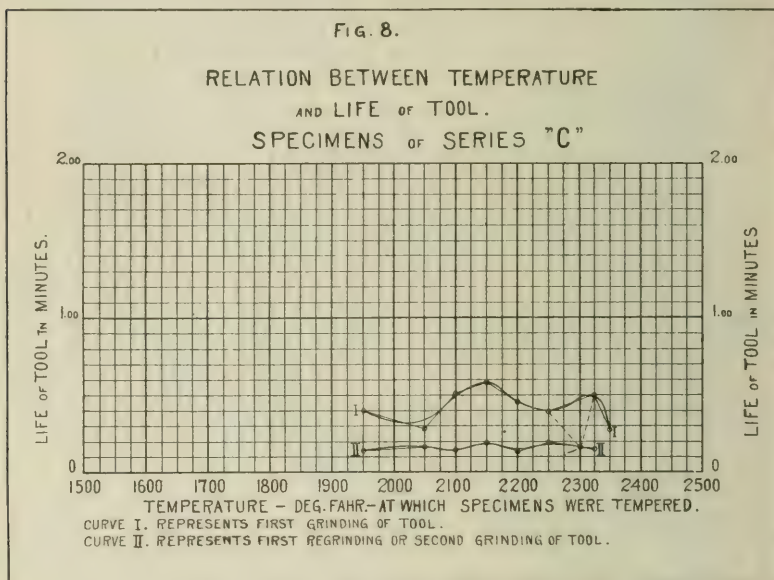
49. Results from the tests run on the specimens of series D are shown by the diagram in Fig. 9. In this diagram it may be noted

that part of the specimens were subjected to a test also after being ground a third time.

50. All three curves (I, II, and III) show the variations very distinctly, and exceptionally high durability, with the attained maximum at the quenching temperature of 2,350 deg. Fahr. for both the first and the second grinding.

51. The specimen quenched at 2,400 deg. Fahr. broke on the second grinding after failing in the length of time (0.52 minutes) as shown in the diagram.

52. Only part of the specimens were run on the third grinding, simply for the reason that the time for boring one cylinder would not be sufficient for the tool to fail at a cutting speed of 80 feet per



"C" Steels—Temperature and Life.

minute. Cutting on more than one cylinder with the same tool would cool the cutting edge of the tool while changing, and the result could not be considered.

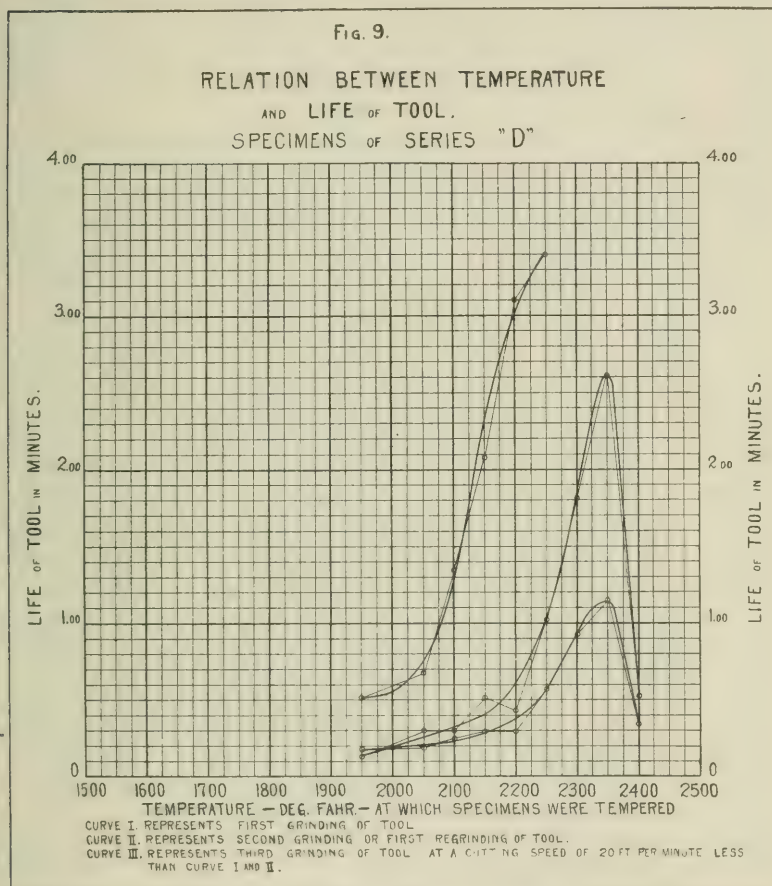
53. The cutting speed, 100 feet per minute for first and second grinding, and 80 feet per minute for third grinding, the thickness of shaving or feed per revolution, 0.0339 inch, and the depth of cut,  $\frac{1}{4}$  inch at each end of the tool, were kept constant for all specimens.

54. In Fig. 10 is shown a diagram giving by percentage the relation between temperature and life of tool, of the four series of specimens. The temperature forms the base of the diagram, and the ordinate is made into a per cent scale.

55. The maximum life or durability of the tool is taken as the unit or put at 100 per cent, and the durability in percentage of the maximum can be read from the curves for any temperature used.

#### METALLURGICAL EXAMINATION BY PHOTOMICROGRAPHS.

56. In examining the photographs of the specimens from series



"D" Steels—Temperature and Life.

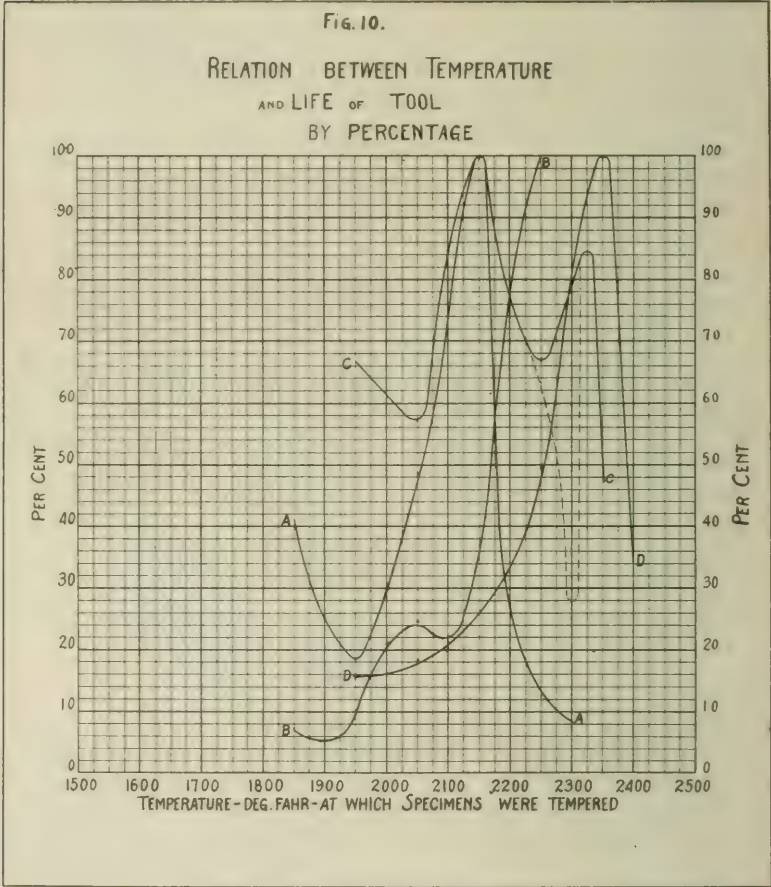
A (reproduced in Plate III), it can be seen that the size of the grain increases with the temperature at which the specimen was quenched.

57. Specimen No. 7, because of its size of grain, absolute freedom from separation of the constituents of the steel, and the absence of the physical defects, which appear in the specimens preceding and following this one, is the one which will be able to best

withstand the vibration and rough treatment of high speed cutting.

58. In specimen No. 0 the hard constituents can be seen to have separated out, forming a network around the steel crystals.

The crystals of the steel under work are forced to move around, rubbing against each other like a ball and socket joint, and this hard constituent surrounding the crystals acts in the same manner as



The Varying Life of Tools from Temperatures.

emery in a ball and socket joint, increasing the friction and generating heat, which will rapidly destroy the tool. This specimen also shows by its physical defects and black structure, (decarburized steel), that the steel was burned.

59. The illustrations from full-size photographs (Plate II) of fractures from the specimens in this series, also indicate clearly the

increasing size of grain with the quenching temperature of the specimen.

60. Examining the illustrations of the specimens from series B (Plate V), it will be seen that the grain of the steel increases gradually up to specimen No. 16, and afterwards very rapidly, showing that the steel is very sensitive to heat treatment above the temperature at which this specimen was treated.

61. For the same reason that specimen No. 7 was chosen as the best of series A, specimen No. 16 is selected of this group. The physical defects which appear in the specimens preceding and following specimen No. 16 are entirely absent here.

62. Comparing this result with the results of the physical test shown in the diagram, Fig. 7, it appears that the two do not agree for this steel. The diagram shows the maximum durability of the series B is attained by specimen No. 19. This occurrence can hardly be accounted for unless it is due to a minimum of separated hard constituents around the steel crystals, even at the higher temperatures.

63. The illustrations from full-size photographs (Plate IV) of the fractures, show the increasing grain with the quenching temperature like the steel in series A.

64. The illustrations of the specimens of series C (Plate VII), show that the size of crystal grains in this group increase gradually up to the point where the steel becomes burned, as shown in specimen No. 30.

65. For this series No. 24 is chosen as the best specimen, because of its clean structure, the absence of any separation of the constituents, and the uniform size of the crystal grains.

66. In specimen No. 30 the steel shows the same effects of burning as specimen No. 0 of series A, the separation of hard constituents around the crystals and the black decarburized spots.

67. Also in this series the illustrations from full-size photographs of fractures (Plate VI) show the increase in size of grain with the temperature.

68. The illustrations of the specimens of series D (Plate IX) show a very uniform structure up to specimens No. 38 and No. 40.

69. Specimen No. 40 shows distinctly marks of being burned, by the black decarburized spots, but the hard constituents surrounding the crystals, which are found in other burned specimens, are entirely absent here.

70. Specimen No. 38 shows a distinct difference from the ones just preceding and following, indicating that this steel has a narrow range of temperature in which it can be treated with the best results. This specimen shows the clearest and cleanest structure and is microscopically the best specimen of the group.

71. In the reproduction of one of the photographs from specimen No. 33 is shown a case referred to in paragraph No. 24. It

illustrates the cracking of a specimen which has been heated too rapidly, and quenched before the heat had been allowed to uniformly penetrate to the center of it. However, it does appear remarkable that this specimen did not break under the physical test.

72. The illustrations from photographs of the fractures (Plate VIII) show the increase in size of grain as in the preceding series.

#### RED HARDNESS AS AFFECTED BY THE STRUCTURE OF THE STEEL.

73. The property named *red hardness* in a high-speed tool steel, and which enables it to cut metal when the cutting edge and near portions are heated to a dull red, should, to a certain extent, be related to the structure of the steel according to the above statements.

74. The heat which is generated by friction between the steel crystals (these being caused to move by vibration), does not destroy the tool as rapidly as the grinding on the crystals by the separated hard constituents, which are present at some temperatures. As the structure of the steel in this case generally consists of crystals of an uneven size, the smaller ones of these are ground to pieces in a comparatively short time, and the cutting edge of the tool is ruined.

75. Therefore, a uniform size of crystals without separated hard constituents between them in the structure of the tool steel, will give a large amount of *red hardness* or high durability, considering the structure of the steel only and apart from the various effects of the chip upon the tool in cutting metals.

76. To find the element, or combination of elements, in the steel responsible for the highest durability, requires the most elaborate experimenting, in the making of the steel, the heat treatments, and the physical tests, and is beyond the object of the experiments described in this paper. However, it is seen that two slightly different chemical compositions of the steel, subjected to the same heat treatment, show a great difference in durability.

77. Taking the results of these experiments as a whole, the general shop rule for treating a high speed tool—"Heat it to a white heat and quench it"—does have its shortcomings, because a variation of 50 deg. Fahr. cannot be determined by the eye.

#### *What are the results of a poorly treated tool?*

78. It decreases the shop production for the manufacturer, who allows it inside his establishment.

It increases the bill of the customer, who pays for the tool and the work spent on it.

When the Works Manager comes through the shop and inquires about the tools, the workman naturally testifies the tool steel to be of inferior quality, which, as we have seen, may not be the case, but this tool steel maker has to find a new market for his stock of steel.

In short, it is waste of energy and waste of capital.

## DISCUSSION.

*Mr. A. Bement* (Chairman): Several years ago, on hearing of some remarkable developments in the improvement of tool steel at the plant of the Bethlehem Steel Company, I took advantage of an opportunity to visit the works. I did not, at the time, however, learn much about the steel in use, but saw much of what it did, and to my mind the plant was the most remarkable example of development in machine-shop practice to that time. The work of Taylor and White was a great step in advance in machine-shop methods. Since then other varieties of similar steel have been developed—some of it better, no doubt. I found that a much larger quantity of work was being done than could be done with carbon steel, and so much work, in fact, that it was necessary to increase the motive power which operated the shop. It also appeared that the lathes were not strong enough to bear the strain which could be put upon them economically in handling steel forgings and similar pieces, and consequently they had to be strengthened.

Another feature which grew out of that possibility of doing so much more work with the new tools was the necessity or the desirability of establishing a system of handling the work. Formerly a man operating a lathe or other tool was given a piece of work with a drawing or other instructions, and he would use his judgment as to the depth of the cut and speed at which he would run the tool; but with the new steel it was found that a scheme, or program, could be made and laid out in advance, so that a man who received a piece of work would also receive instructions as to the depth of cut and the speed at which the piece would turn. I also found that a man called a speed foreman, went about the shop, to see that the instructions were carried out in the most advantageous manner. It greatly interested me to see tools running red hot, turning out chips that were heated so that they became dark blue as they rolled away from the tools. That was quite a remarkable sight to a man used to old-fashioned steel, which would be ruined long before it could become red hot, and if worked at too great a speed it would lose its point and become useless in a very few moments. It also appeared that while the steel was suitable for heavy, coarse, rough work, it did not lend itself so well to the finer finishing-cuts; for such work I found the old carbon steel was being used. It may be a matter of interest to know whether any of the modern steel is as well suited to finishing-cuts as it is to rough work.

It is often said that a little knowledge is a dangerous thing,—it might be said, a bad thing. In tempering steel, and in many other metallurgical processes, judgment has largely prevailed, which is probably better defined as an educated guess. Many people seemed qualified to guess fairly well, and this practice continued for a long time, but we have in the paper presented

this evening an illustration of the advantage of applying an exact method.

In this connection I am reminded that at the Bethlehem Steel Company's plant one man did all of the tempering, his knowledge of temperatures being confined entirely to his own judgment. It was considered, at the time, quite a step in advance that the tempering was all done by one person instead of by several; in fact, the scheme was considered to be quite scientific. Today, however, in the light of present knowledge, the idea seems crude.

*Mr. A. D. de Pierrefeu*, (Illinois Steel Co.): Referring to my work in connection with these experiments, as Mr. Berg has said, we found that the steel which had been treated at a high temperature seemed to have a segregation of certain hard constituents in the grain of the specimen. I observed this fact on several occasions, while examining, with the microscope, some steel plates to which had been added 0.3 of 1% of ferro titanium. As the constituents were segregated in too small particles to be isolated for chemical analysis or scleroscope test, I was obliged to judge of their hardness by their resistance to polishing. I took the specimens which had been very carefully polished, and examined them under the microscope before etching them. Certain parts were out of focus, when the rest of the specimen was properly focused, and in running the microscope's stage away from the microscope the unfocused parts became focused, showing that they were standing out of the polishing plane and therefore had a greater wearing quality than the rest of the specimen.

When Mr. Berg gave us the samples for microscopic analysis, he purposely did not tell us which ones had given him the best results. When we were through with our investigation, on comparing notes with Mr. Berg we found that our conclusions were identical.

*Mr. George N. Prentiss*, (C., M. & St. P. Ry.): I came here to find out something about high-speed steel. I do not feel that I can add any information to what has already been given, but I have had some experience in guessing temperatures of iron and steel by color, and I made up my mind a number of years ago that it was not even a guess—that if one can come within 200 degrees rather than 50 he has a reasonably good eye and is a reasonably good guesser.

I will ask Mr. de Pierrefeu what method he found the best for etching those hard steels.

*Mr. de Pierrefeu*: Nitric acid, about 5%.

*Mr. Prentiss*: The method of heating high-speed steels as much as possible without melting them, and then quenching them, has given very poor results. Although we have not made experiments in the way that Mr. Berg has (they have been more in the nature of shop-experiments than anything else), we have

secured our best results at about 2,100 deg. That is the average of the different grades of high-speed steel we have used. Possibly if we had gone to 2,150 deg. we would have secured still better results.

*Mr. W. A. Gowing, (Bethlehem Steel Co.):* I have listened with a great deal of interest to Mr. Berg's paper showing the results of tests conducted by him, and feel that the care which he has exercised in obtaining his determinations, and in avoiding any possibility of the personal equation entering into them, has made them most conclusive in the particular tests referred to.

The selection of the steel, the manufacture of the cylinders on which the tests were based, and the care taken in the heating and treating of the tools, have certainly been most thorough, and I believe that every one here appreciates the efforts which Mr. Berg has expended, and all feel that we are one step nearer a common point.

Although the present paper deals entirely with high-speed tools, I am awaiting with a great deal of interest the subsequent results obtained by Mr. Berg from his experiments on carbon steels. My experience has taught me that a great deal more care and judgment must necessarily be exercised in the treating of carbon steels than is the case when treating high-speed tool steels. The limits of heating and treating the former, together with the subsequent drawing of the temper, are narrower, and are not generally understood by the majority of smiths. The determining of the critical, or decalescence, point presents one of the most serious problems in the hardening of carbon steels. The shape and design of the tool, or die, frequently affect the carbon content of the desired steel. The critical point can also be determined in a Tungsten steel, but in the hardening process this temperature is often exceeded 300 or 400 degrees.

Mr. Berg's demonstrations in the cutting tests, where, after the second grinding, he invariably increased the speed 25%, seem to prove this increase a constant factor. That point was further demonstrated in his subsequent remarks on red hardness, when he advised that practically the same, although not as effective, results were obtained by permitting the tool to heat up in cutting to the point indicating red hardness, and allowing it to cool, as he would have obtained by a second treatment after once hardening.

We believe, however, that where a second treatment can be effected, the life of the tool is considerably increased. This refers particularly to such shops as have a treating-equipment for their tools which is consistent with their requirements. I am glad to state that many concerns today are paying more attention to the heating and treating of the steels which they use, not only for cutting purposes but in their general work. This will be a great advantage to the steel manufacturer, who up to this

time has certainly been taken advantage of in the matter of defects.

The cutting, cold, of high-speed steels often causes invisible cracks, which develop later in the subsequent forging and tempering operations, and which are promptly referred to the steel maker. Heating unevenly in a fire, too rapid heating, or hammering too cold, will often cause cracks and hammer-bursts, which are also promptly referred to the manufacturer. While it is possible that some of these defects can occur in the forging of the steel at the manufacturer's plant, nevertheless the heating and handling facilities, and specialists employed in this class of work, are such as to make it almost improbable. The steel maker, I believe, however, is perfectly willing to stand his share of these responsibilities.

*Mr. Bement:* What is the system of measuring temperature and tempering at Bethlehem?

*Mr. Gowing:* The experiments at Bethlehem date back to 1897. Since that time high-speed steels of almost every combination chemically, have been treated through all ranges of temperature from 1300 deg. upward, and the results were obtained and recorded from tests on a forging of about 1.00% carbon, and also from a series of tests on a forging of about 0.34% carbon, with a view of noting the comparative effect on high and low carbon forgings.

The tools are heated slowly and thoroughly in a muffle furnace, governed by a LeChatelier pyrometer, are then brought up to practically the fusing or melting point, and placed in a large lead bath, which is kept at a constant temperature of 1150 deg., and subsequently cooled under a blast of air. After cooling, they are again preheated and put in this lead bath of 1150 deg. until thoroughly soaked and are then put under a blast of air.

Where the equipment in outside shops does not permit of a treatment of this kind, we have found that excellent results were obtained from a good, live, soft-coal or coke fire, or a temporary muffler built over a blacksmith's fire. The tool should then be heated up slowly and thoroughly until a bright-cherry color is reached, and then, by forcing the blast for a few minutes, depending on the section of the tool, the temperature is run up to the fusing heat, and cooled in the air blast. We feel that the principal operation is the heating, together with the time and nature of cooling. We have found also that the subsequent grinding of tools has an important bearing on the results obtained, as a high-speed tool can readily be affected by over-heating on an emery wheel, developing heat-cracks which may later result in breakages.

*Mr. Bement:* We would like to know whether you use high-speed steel for finishing cuts.

*Mr. Gowing:* We have used high-speed steels for finishing

in a number of instances, such as rolls, roll-bodying, roll-necking, and in general machine-shop work, where the degree of finishing is what might be known to the trade more as a smoothing cut. We make a special Tungsten steel, however, which is used for the finest grades of finishing, the edge being retained for a long cut.

*Mr. W. F. Young*, (Hoskins Mfg. Co.): I wish to express my appreciation of Mr. Berg's paper, as being the first definite information that I have been able to secure regarding the heat treatment of high-speed tool steels.

The general impression seems to have been that there was no definite temperature for the treatment of high-speed steel, as long as it was heated to a high enough temperature, and it has generally been believed that this temperature was not reached unless the steel was hot enough to sweat freely, or had been brought to the dripping point.

If there is a definite temperature at which different makes of high-speed steel should be treated, as Mr. Berg's paper has brought out, it will be of great value to the majority of users of high-speed steel to learn this, as it will enable them to get nearly 50% more use out of their steel.

*Mr. James Aston*, (Northern Chemical Engineering Laboratories, Madison, Wis.): I am not a member of the Society, but came here to listen to what Mr. Berg had to say. I am sure that I have learned a great deal. I had not intended to take part in the discussion, because I have really no direct comments to make; but we have been doing a little work at the University of Wisconsin which it may be well to bring forward at this time,—a little experimental work on the uniformity of steels. Mr. Berg has brought out quite clearly the necessity of care and skill in the manipulation of the material. That represents probably half of the necessary care and skill. Perhaps the other half is the skill of the maker. I do not think I am much out of the way in saying that anybody can make a good tool-steel sometimes, but the important thing is to make it all the time,—that is, to get a uniform product,—and I believe it is safe to say that to get a medium grade of material, always the same, is much better than to get an excellent grade of material that does not hit the standard all the time. I believe there are three classes of variables that enter into the manufacture of steel tools,—the initial composition of the stock, the skill in the melting of it, and then this subsequent skill in the manipulation of the material, which Mr. Berg has dwelt upon. The composition plays a large part. This, I think, is shown in the fact that tool-steel makers still cling to the more expensive Swedish iron that they have always used, because it has that body—whatever it is—which they want and do not get in the open-hearth material of seemingly as good quality. Probably it lies in the sulphur and phosphorus, and to a

great extent in the dissolved oxides. I think that is the reason they adhere to the crucible furnace, because they get the proper atmosphere; and this is confirmed by their adoption of the electric furnace, where one can control the atmosphere and besides get a higher temperature, which probably means a better diffusion of the elements. The third variable I think is dependent on the other two; that is, lack of uniformity in the first two conditions makes necessary greater skill in the subsequent manipulation of the tool.

I am bringing these matters to your attention because we have been carrying out experimental work at the University on iron obtained by the electrolytic process. I believe Professor Burgess has spoken before this Society of the method. Our work up to this time has been largely in the determination of the effect of the alloying elements, in the absence of carbon and other impurities. This has mainly a scientific interest, however, since unless some exceptional properties should be observed, the material could hardly be put on the market for structural purposes, because the refining is an expensive operation. Lately we have gone on a different tack. We have this electrolytic iron of high purity. We know that the sulphur and phosphorus are negligible and that the oxides are not there. Why not use it for tool steel? That fills one condition. The second we reach by the use of an electric furnace, giving the proper atmosphere and high temperature. The third feature—the manipulation—we control by electric heating for muffle furnace and barium-chloride bath, and by the use of the pyrometer. The results are not complete enough to make any sweeping statements; but I can say this, that the influence of purity is shown by the fact that we made, under identical conditions of composition and treatment, two carbon tool steels; for one we used the high purity iron, for the other ordinary Swedish stock; and in all cases which we have tried out, we obtained results that averaged 50% better from the material of higher purity. Also, in the electrolytic stock, we get that extremely fine tempering grain, and under the microscope there is little evidence of such impurities as the oxides to be seen in Swedish stock. Some of these were evident in the photomicrographs shown tonight.

In regard to comparisons with high-speed steels, we have not yet gone far enough. But in what work we have done the results compare favorably with the steels on the market today.

What I desire to bring out is the point that if we can get that absolute uniformity of pure iron as a basis on which to start, and then use those other methods that are now coming in,—like the electric furnace and the pyrometer,—to control the manipulation of the tool, we are going a long way towards eliminating the personal equation, that bugaboo in tool-steel manufacture, dependent on the skill of the man who handles it.

*Dr. J. W. Lawrie*, (International Harvester Co.): I note one thing in series B. The steel was hardened at 1850 deg. and the hardness test showed 78; then another sample was hardened at 1900, 1950, 2000, and then 2050 deg.; the hardness dropped at 1900 and then gradually rose again. I would like to know if Mr. Berg has any reason for this. Also if the cutting at 1850 was better than it was at 1900, say, where there was considerable difference in the hardness? Were any cutting tests tried at 1850?

*Mr. Berg*: Referring to Fig. 7, it will be seen that the durability at 1850 does not show any higher than the one at 1750, as a matter of fact, the 1750 goes a little higher than the 1850. However, at those lower temperatures there does not seem to be any definite increase or decrease in the durability or the life of the tool. It does not appear very distinctly before we get up to the higher temperatures, nearer up to the right points, and, as stated in the paper, I do not know, myself, how to account for the maximum durability attained at the highest heat-treatment but that there are no hard constituents or impurities separated out in the structure of the steel.

*Dr. Lawrie*: Have you found, Mr. Berg, that the best life is due to uniformity of structure or fineness of structure?

*Mr. Berg*: Uniformity of structure appears to be the best to secure life in the tools, although the grains appear also to be uniformly small in the structure that is the most even or the finest, and which attained the maximum durability. The grains seemed to be increasing up to a certain temperature, where they all seemed to become even; then after that they increased more rapidly and impurities and hard constituents separated out at very high temperatures, and some elements started to burn out. A small, even-sized grain appears to be the best structure.

*Mr. F. P. Kellogg*, M. W. S. E.: I will mention a method of determining the temperature of steel which I have known for about twenty-five years, and which was practiced in the Cumberland Mountains by a blacksmith. He was celebrated, as well as his father, for making rifled guns and knives. He had a test piece of lead, a piece of sycamore, a piece of beech, and a piece of what was called basswood. By touching or approaching the heated steel to these different articles he would have a scale and make of himself what we would call a human pyrometer. He made a gun, weighing about 24 lb., with tools that he had made, boring it out himself. That gun was celebrated all over the country in "turkey shooting" contests. He also made a bayonet attached to the gun, with the edge of which he could cut, with one stroke, telegraph wires as they were suspended between poles. That bayonet was taken off the gun by the Rebels and used in the Civil War for a sword.

The blacksmith's method was a remarkable one for deter-

mining temperatures which he wished to obtain for his various tool-steels, and was quite a little better than a guess by the color of the glow in twilight. I have not heard this method mentioned tonight, and thought it would be well to give the credit for it to a mountaineer in the Cumberland Mountains,—a self-taught mechanic, of necessity best adapting his means to a desired end.

*Mr. P. J. Myall:* I will ask Mr. Berg what grade of oil he used in quenching those tools with which he carried on the experiments?

*Mr. Berg:* The oil used was fish oil, although cotton-seed oil will answer the same purpose, and the latter is mostly used in practice.

*Mr. R. G. Mershon, M. W. S. E.:* Do the different qualities of raw ore have any effect in the manufacture of high-speed tools? I understand that there is a great difference in the quality of iron ore from the different mines, and in Minnesota I have heard the assertion (of course the people of Minnesota are interested in their own state, particularly) that the best quality of iron ore is found there.

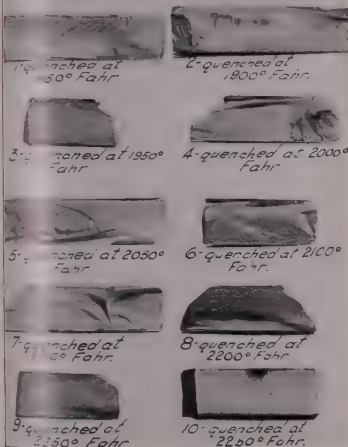
*Mr. Berg:* I am not in position to answer this question, because I have not been closely enough associated with the steel manufacture itself. Of course, as we have already heard this evening, the purity of pig iron is an important factor in connection with tool steel, as well as the different chemical elements, the amounts of them, etc. These things have a great deal to do with the durability of a high-speed tool, which durability might be said to be the amount of red hardness, enabling the tool to cut metal with the cutting edge heated to a red heat.

*Mr. L. A. Touzalin, (Illinois Steel Co.):* Any one who has experienced the difficulty that I have encountered recently in searching for literature on this subject, knows how scarce are articles of this kind. The Illinois Steel Co. has, within the last few months, established a "special steel" department at the South Works, so we are all interested in this question, and have tried to find such articles as the one presented tonight.

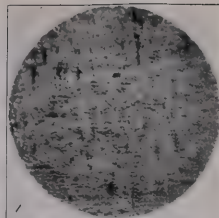
The question naturally arises, why have we been so lax in adopting scientific methods of obtaining temperatures before quenching steel? I believe the one serious drawback in the past has been the lack of good, thorough, and accurate instruments which were simple enough to do the work in such a way that the average shop-workman could get the results. In this connection I believe that the Hoskins Mfg. Co. have greatly aided manufacturers and those treating tool steels with their pyrometer. As a constant user of their apparatus I cannot refrain tonight from giving a little testimony as to what invaluable aid it has given us in the laboratory at the South Works. Before we used any of their pyrometers or combustion furnaces we were in about the same position as the gentleman who spoke of

# PLATE II

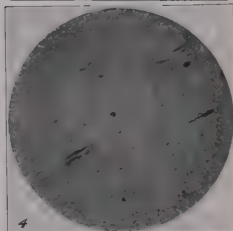
Features from specimens of Series A



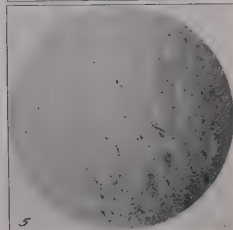
Quenched at 1850° F



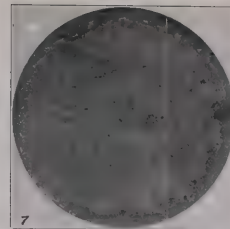
Quenched at 2000° F



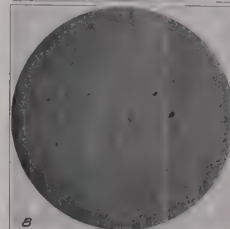
Quenched at 2050° F



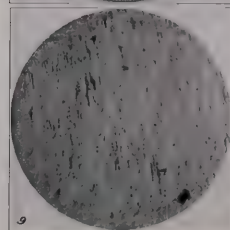
Quenched at 2150° F



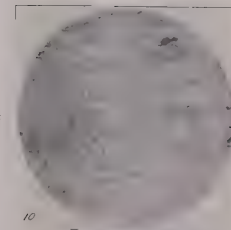
Quenched at 2200° F



Quenched at 2250° F



Quenched at 2250° F



Quenched at 2300° F

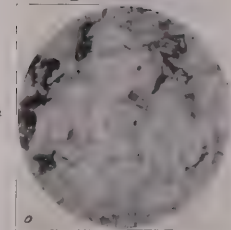
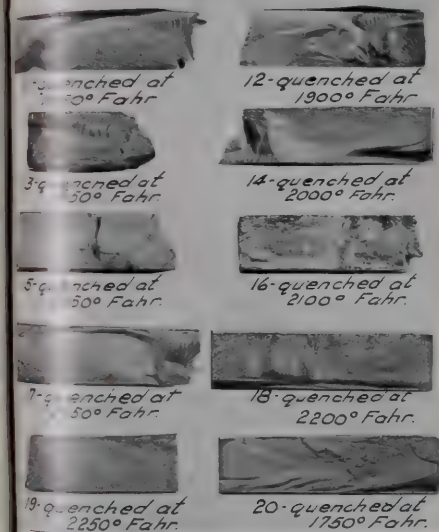


PLATE III.  
Photomicrographs.  
300 diameters.  
SPECIMENS.  
Series A.

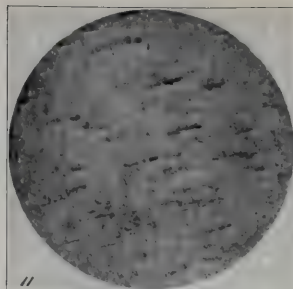


# PLATE IV.

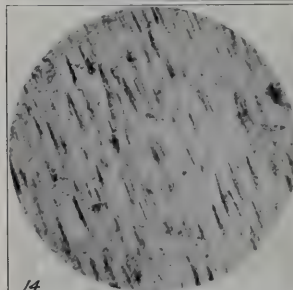
Features of specimens. Series B.



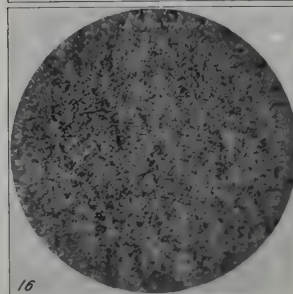
Quenched at  
1850° F.



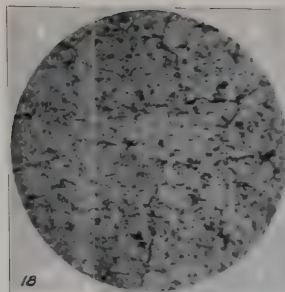
Quenched at  
2000° F.



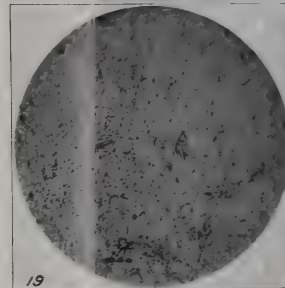
Quenched at  
2100° F.



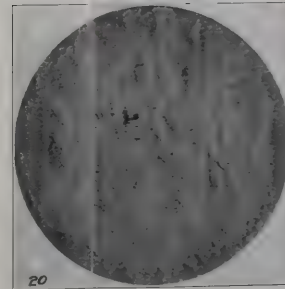
Quenched at  
2200° F.



Quenched at  
2250° F.



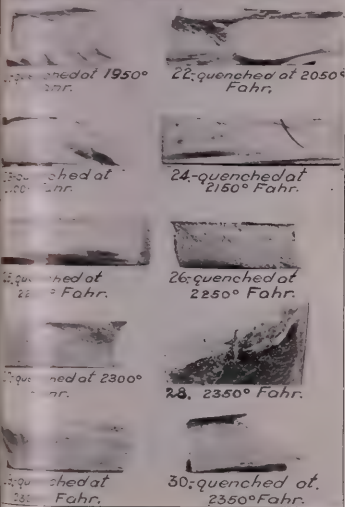
Quenched at  
1750° F.



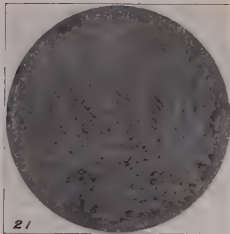


# PLATE VI.

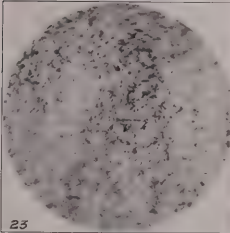
Microstructures of specimens Series C



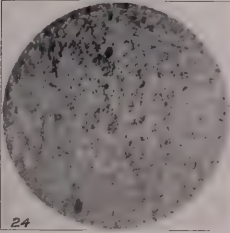
Quenched at 1950° F



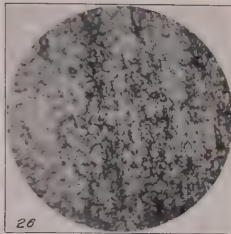
Quenched at 2100° F



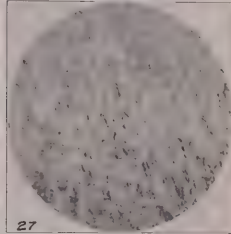
Quenched at 2150° F



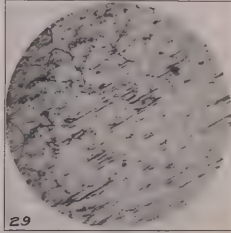
Quenched at 2250° F.



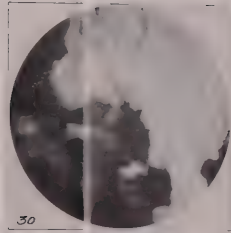
Quenched at 2300° F.



Quenched at 2325° F.



Quenched at 2350° F.



Quenched at 2350° F.

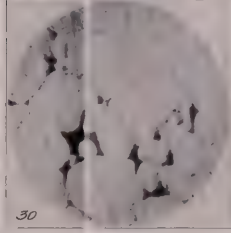
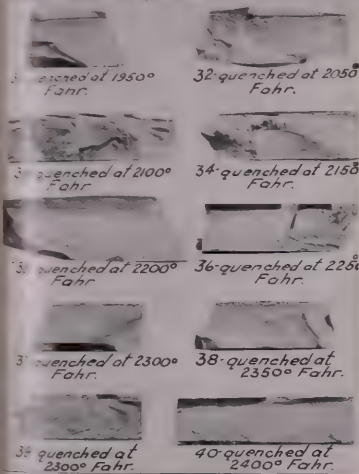


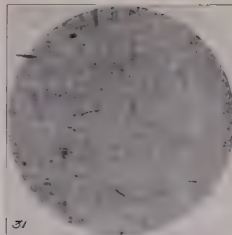
PLATE VII  
Photomicrographs,  
300 diameters,  
SPECIMENS  
Series C



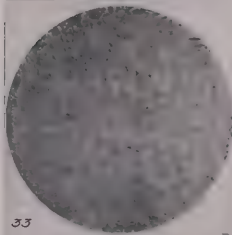
PLATE VIII.  
Features from specimens of Series D.



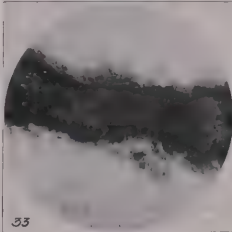
Quenched at  
1950° F.



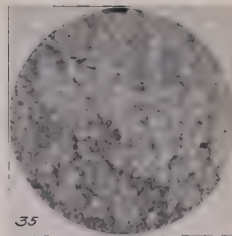
Quenched at  
2100° F.



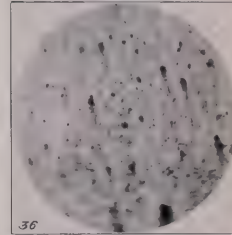
Quenched at  
2100° F.



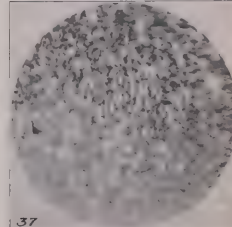
Quenched at  
2200° F.



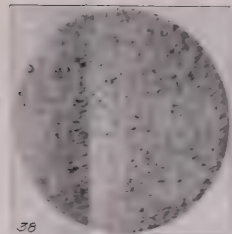
Quenched at  
2250° F.



Quenched at  
2300° F.



Quenched at  
2400° F.



Quenched at  
2400° F.

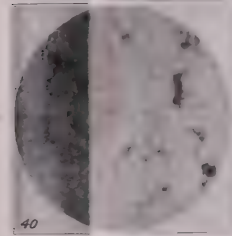


PLATE IX.  
Features from specimens  
of Series D.  
SPECIMENS  
Series D.



having used the method of guessing at the temperature, and I presume we were making just as bad mistakes as he probably did. This reminds me of a little occurrence which I am informed took place at the South Works. They had a man who had been in that kind of work ten years, more or less, and was considered a human pyrometer. One of the superintendents asked him if he really could tell the temperature of molten pig-iron. He replied "Yes, within 50 or 25 degrees." They brought up a recording pyrometer, which had been out of sight, and focused it on the pig iron. The man turned white and began to make excuses right away. When they began to take temperatures they found he was as many as 200 to 500 degrees off.

In our combustion work on carbons we use the Hoskins combustion furnace and each furnace is connected with one of their pyrometers with an illuminated dial so that it can be readily seen at night. These have been in continuous service for over nine months and we have not yet had a burn-out. When we can get such apparatus, which is reliable, durable, and robust, and which the average man can handle, it seems to me that there will be no excuse in the future for any guesswork in this line of work.

*Mr. Cement:* Mr. Touzalin has referred to the 15-ton electric furnace at the plant of the Illinois Steel Co. I will ask him if tool steel has been made with that furnace?

*Mr. Touzalin:* Up to the present time they have not attempted to make any tool steel, but it is possible that in the future they will attempt to do so. They have, however, made nickel and chromium steel, and some manganese steel, I think.

*Mr. Cement:* I suppose that results much superior to those from the ordinary open hearth have been secured?

*Mr. Touzalin:* Yes, you are correct in your supposition.

*Mr. Prentiss:* During the last three or four months, the C. M. & St. P. Ry. Co., in treating all high-speed steels, used the barium-chloride bath and pyrometer, and heated the tools to about 2100 deg. before quenching, and the results in shop practice have been much better than when the barium-chloride bath was used and the temperature was guessed at. I should think the improvement was at least 20% in the life of the tools.

*Mr. George M. Mayer, M. W. S. E.:* Would not the low temperature treatment be better for tools used on hard iron? Mr. Berg has used the tools on hard iron and the tools lasted only a few minutes, but under the ordinary conditions the tool would last some time. Under the latter condition would not the low-temperature treatment be the best?

*Mr. Berg:* In regard to using the tools on softer metal, I have not found that there is any variation in a comparative test between temperatures; the life of the tool would be materially increased for all temperatures, but with the same relation be-

tween the comparative temperatures; that may be seen to some extent in one of the charts where the cutting speed was varied from 100 to 80 feet per minute, where the durability attained was of a much higher degree, but with the same relations between the different temperatures. In using the tools on a softer casting, I did not find any different variation in durability or relations between temperatures, to indicate the necessity of a different temperature for the maximum durability of a tool for cutting softer castings, and the reason for that is, I think, that as most of those tools have been seen to attain the maximum durability where the most homogeneous structure or even size of crystals have been, no other temperature for that particular steel would do as well, even if it was used on a softer kind of material. A tool that is treated for cutting on one kind of material must have its highest durability at the same point for another kind. That is at least my experience in using these tools.

## EARTH PRESSURES.

CHARLES K. MOHLER, M. W. S. E.

*Presented April 6, 1910.*

*A study of the sliding prism theory of Vauban after the graphics of Rebhann and of the analytical theory of Rankine, showing lack of agreement, and break-downs in the theories when worked out for results; also formulæ and results from a new method.*

There is no department in the whole field of engineering which can be charged up with so great a proportion of failures or partial failures as that relating to the design and construction of abutments and retaining walls. Until very recently there has been almost no progress made in designing structures of that class that will stand up without showing signs of weakness or failure.

While we are greatly in need of more reliable and exact data relating to earth pressure than we now possess, there is one erroneous dogma, which we should lose no time in getting away from absolutely. That is the old text-book statement that "If the wall is designed so that the resultant of the forces acting on the base, cuts the base inside the middle third the wall is safe against overturning." Under some conditions nothing could be much farther from the truth. Unless we are to be satisfied with a tipped and cracked wall, *it is a safe rule for only one condition*; that is where there is a rigid and unyielding foundation such as solid rock. Unfortunately rock foundations are the exception rather than the rule for ordinary walls.

With a compressible or yielding foundation you cannot expect anything but a cracked or failing wall when the foundation reaction at the toe of the wall is greatly in excess of that at the heel, which the middle-third theory allows and usually gives. Piling is often used to correct the evil and take care of the excessive toe pressure, but even that method, while adding greatly to the expense, often fails to prevent settlement and cracks. The only safe rule is to so design the wall that the resultant will pass through the center of the base, or perhaps a little better, just back of the center.

The misconception of the middle-third theory and its application has alone been responsible for most of the failures and partial failures of retaining walls and abutments.

Fig. 1 shows clearly a typical case of a wall having tipped forward on account of excess toe pressure, and consequent settlement.

### THE EARTH PRESSURE AFFECTING THE FOUNDATION REACTION.

In the treatment of wall design we are at once confronted with the question, what is the amount and direction of the

earth pressure against the wall, and how does it affect the direction of the resultant foundation reaction, and the determination of the point at which it cuts the base.

It has long been recognized that the data and formulae relating to earth pressure are not as complete and reliable as we should have for correct designing, but for most conditions they are unquestionably better than guessing or working in the dark. Many of the formulae and resulting computations are very



Fig. 1. Characteristic Settlement Crack, Due to Excess Toe Pressure.

long and complicated, and it is almost a hopeless task to work out results for use and comparison.

#### PREPARATION OF TABLES, FROM OLD THEORIES.

In order to get data in shape for convenient use and comparison, based on such theories and formulae as were available,

the author computed tables\* of constants  $C$  (so-called) for a large number of varying conditions governed by angles of repose or natural slope, back of wall batters, angles of surcharge, etc.

*First*, from the Analytical Theory of Rankine, of 1856.

*Second*, from the Sliding Prism Theory of Vauban, 1687, Coulomb, etc., after the graphics of Rebhann, of 1871.

After the tables were completed it was found, on comparison, that there was only one set of assumptions in which the two methods gave the same values. Namely, with vertical back of wall, and fill level back of wall.

To mention only one case of disagreement at this point; for the angle of repose or natural slope of  $45^\circ$ , surcharge of  $45^\circ$ , and with the back of wall batter away from the fill at an angle of  $33^\circ 42'$  with the vertical, Rankine's formula gives the value of the constant  $C$  as 144 lb., while Rebhann gives only 84 lb. Then again, neither theory gives self-consistent results throughout. Some of the points of divergence between the two theories, as well as the break-downs in the theories themselves, are clearly shown in the accompanying Figs. 2, 3, 4, 5 and 6.

Before discussing the figures it may be well to state the conventional abbreviations which are used. As Greek letters have been almost universally used in the treatment of earth pressure, a few of those in most common use have been retained, as follows:

$\phi$  = the angle of repose or natural slope of the earth or fill, measured from the horizontal.

$\phi'$  = the angle of friction between the earth and the back of the wall.

$\epsilon$  = the angle of surcharge of fill back of wall with the horizontal.

$\alpha$  = the angle which the batter of the back of wall makes with the vertical; *positive* when the back batter slopes up *away* from the fill and *negative* when it slopes up *toward* the fill.

$\delta$  = the angle which the direction of the resultant earth pressure makes with the horizontal.

$\gamma$  = the weight in pounds per cu. ft. of the earth fill or backing.

$h$  = the height in feet of fill or backing retained.

$P$  = the horizontal component of the earth pressure.

$W_c$  = the weight of earth carried on the wall foundation and is the vertical component of the earth pressure, being derived from the earth wedge over the back of wall batter.

$E$  = the total earth pressure acting against the back of the wall.

$C$  = the constant (so-called) of the tables, and has the same value as  $E$  when  $h = \text{unity}$  and  $\gamma = 100$ .  $E$  for any value

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\*Tables published in Engineering News, Vol. 62, No. 22, Nov. 25, 1909, page 588.



EARTH PRESSURE CONSTANTS (C) AND ANGLES OF RESULTANT ( $\delta$ ) WITH HORIZONTAL; FOR DIFFERENT ANGLES OF SLOPE ( $\phi$ ), INCLINATIONS OF SURFACE ( $\alpha$ ) AND BACK OF WALL BATTERS ( $\alpha_1$ ). SLIDING PRISM THEORY. COULOMB AND REBHANN. FROM PRELIM.

[illegible]

TO OBTAIN THE EARTH PRESSURE  $E$  MULTIPLY THE CONSTANT  $C$  BY THE SQUARE OF THE HEIGHT

of  $h$  equals  $h^2C$ . ( $C$  is termed a constant for the reason that when once computed for any set of conditions the corresponding value of  $E$  is derived for any height  $h$  by squaring  $h$  and multiplying into  $C$ .)

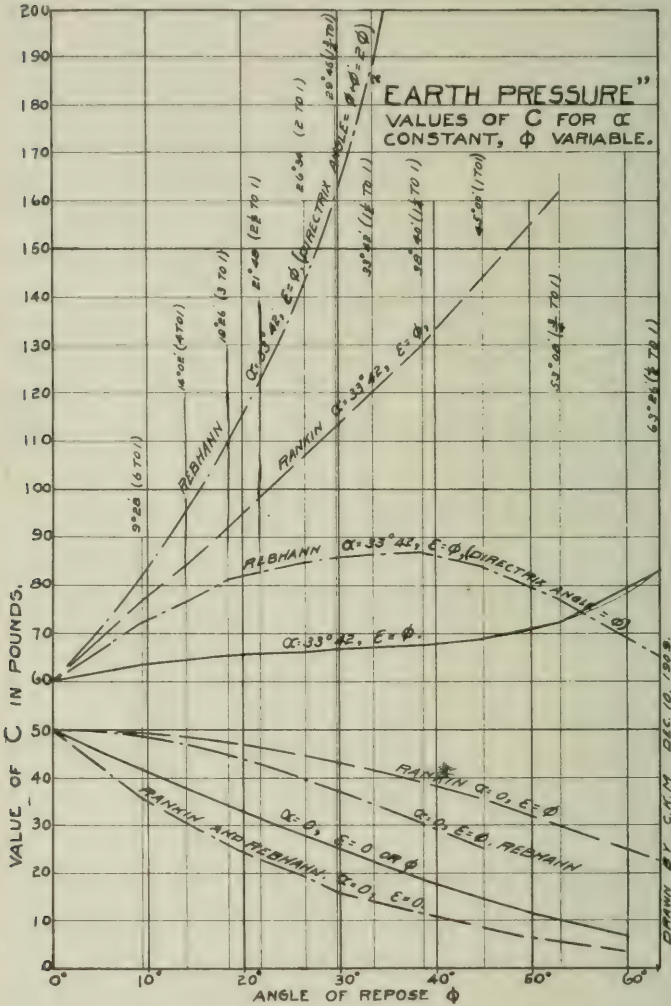


Fig. 2. Platted Values for  $\alpha=0, \epsilon=0$  and  $\phi$ .  
Also  $\alpha=33^\circ 42', \epsilon=\phi$ .

In Figs. 2 and 3 the angle of repose  $\phi$  is platted as abscissa and the constant  $C$  in pounds as ordinates. The back of wall batter angle  $\alpha$  is constant for a given curve or group of curves. In Figs. 4, 5 and 6 the back of wall batter angle is platted as

abscissa. Positive values of  $a$  are given on the right of zero, and negative on the left.  $C$  is plotted as ordinates as before. All values of  $C$  and  $E$  are for a portion of earth or wall one foot or unity in length.

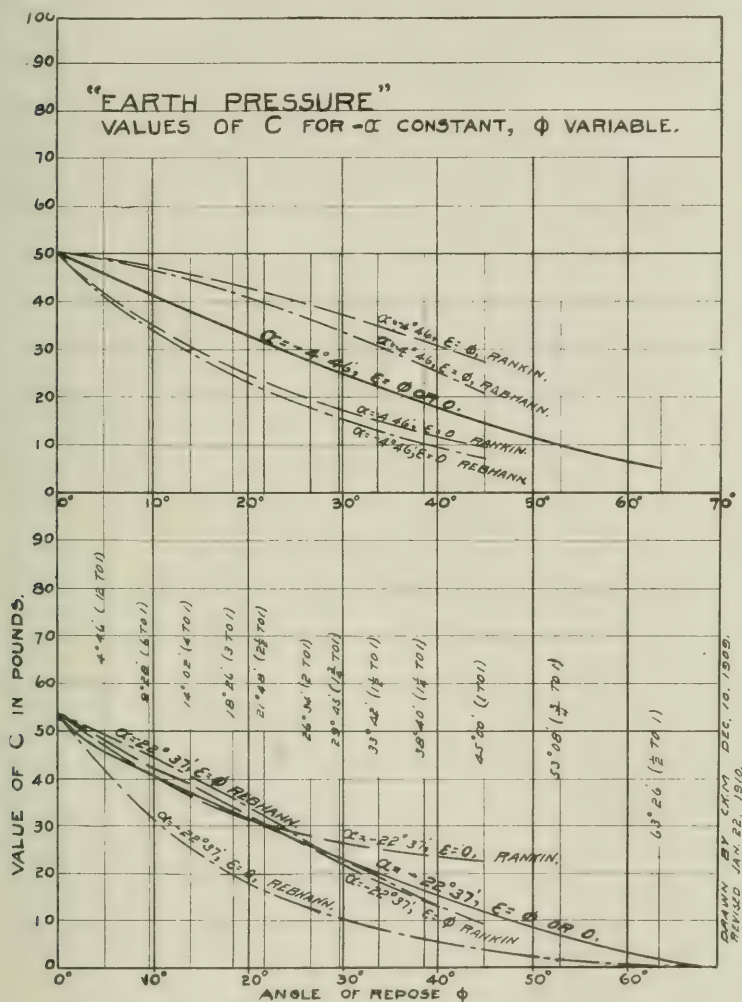


Fig. 3. Curves for  $a = -4^\circ 46'$ ,  $\epsilon = 0$  and  $\phi$ , and  $a = -22^\circ 37'$ ,  $\epsilon = 0$  and  $\phi$ .

CHARACTERISTICS OF CURVES FOR BACK OF WALL BATTER CONSTANT.

By referring to the figures the following will be noted:

In Fig. 2 the curve for back of wall batter  $a = 0$ , and surcharge  $\epsilon = 0$ , Rankine and Rebmann both give values for  $C$

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that agree. For  $a = 0$ , and  $\epsilon = \phi$  (angle of repose) Rankine gives increasingly higher values for  $C$  than Rebhann, as the angle  $\phi$  increases from zero or hydrostatic pressure.

For the positive back of wall batter  $a = 33^\circ 42'$  and angle of surcharge  $\epsilon = \phi$ , Rankine gives what would appear to be excessively high values for  $C$ . Rebhann gives a relatively rapid increase from  $\phi = 0$  (hydrostatic pressure) up to a slope 3 to 1 ( $\phi = 18^\circ 26'$ ), and but moderate increase up to  $1\frac{1}{4}$  to 1 ( $\phi = 38^\circ 40'$ ). At a slope of  $1\frac{1}{4}$  to 1 there is a break-down and the values of  $C$  rapidly decrease. That is from the graphical determination in which friction against the back of the wall is not considered. On the other hand, when friction against the back of the wall is considered and taken at  $\phi' = \phi$ , the same graphics, see curve "Rebhann  $a = 33^\circ 42'$ ,  $\epsilon = \phi$  (directrix angle  $= \phi + \phi' = 2\phi$ )" gives values for  $C$  that are high beyond any reason. For this particular case we get what may be termed a double break-down in the sliding prism theory, while as above stated Rankine gives very high values.

In Fig. 3 curves are shown for  $a = -4^\circ 46'$ ,  $\epsilon = 0$  and  $\epsilon = \phi$ . Also for  $a = -22^\circ 37'$ ,  $\epsilon = 0$  and  $\epsilon = \phi$ . The apparent disagreement between the two theories is not so great, with one exception, as in the previous cases shown, and there appear to be no complete break-downs except in Rankine  $a = -22^\circ 37'$  and  $\epsilon = 0$ . The exceptional disagreement is also for  $a = -22^\circ 37'$   $\epsilon = 0$ . For example, for  $\phi = 45^\circ$  Rankine gives the value of  $C$  equal 22.5 lb., while Rebhann gives only 3.1 lb. The result from Rankine is over seven times as great as that obtained from Rebhann. As shown later, however, Rankine's theory breaks down for all negative back of wall batter angles,  $a$ .

#### CHARACTERISTICS OF CURVES FOR ANGLE OF REPOSE $\phi$ CONSTANT.

In Figs. 4, 5 and 6, as previously stated, the back of wall batter angles,  $a$ , are platted as abscissa, with  $\phi$  and  $\epsilon$  constants for a given curve, and  $C$  as ordinates. Fig. 4 shows curves for  $\phi = 45^\circ$  and  $\epsilon = 0^\circ$  and  $45^\circ$ . For comparison, the curve for  $\phi = 0^\circ$  or hydrostatic pressure is platted in the dotted line.

For  $\phi = 45^\circ$  and  $\epsilon = 0$ , Rankine and Rebhann give the same result, when  $a = 0$ . With  $a = 45^\circ$ , Rankine gives a much higher value than Rebhann. For negative values of  $a$ , Rankine gives rapidly increasing values of  $C$ , while they should manifestly be decreasing. Rebhann gives decreasing values with the curve convex downward. Of course a negative back of wall batter angle of  $45^\circ$  is outside of any probability, and the values were only calculated to show the character of the curves in reaching that limit. With the angle of repose  $\phi = 45^\circ$ , and a negative back of wall batter of  $a = -45^\circ$ ,  $C$  must reduce to zero. For  $\phi = 45^\circ$  and  $\epsilon = 45^\circ$ , Rankine gives excessively high values for  $a$  positive. For  $a$  negative they run down to a

fairly consistent termination. Rebhann gives much lower values with  $a$  positive, while for  $a$  negative the results coincide with those from Rankine from  $-14^{\circ} 02'$  to  $-22^{\circ} 37'$ . After passing  $-22^{\circ} 37'$  they again diverge, Rankine giving the greater values until the limit of  $-45^{\circ}$  is reached.

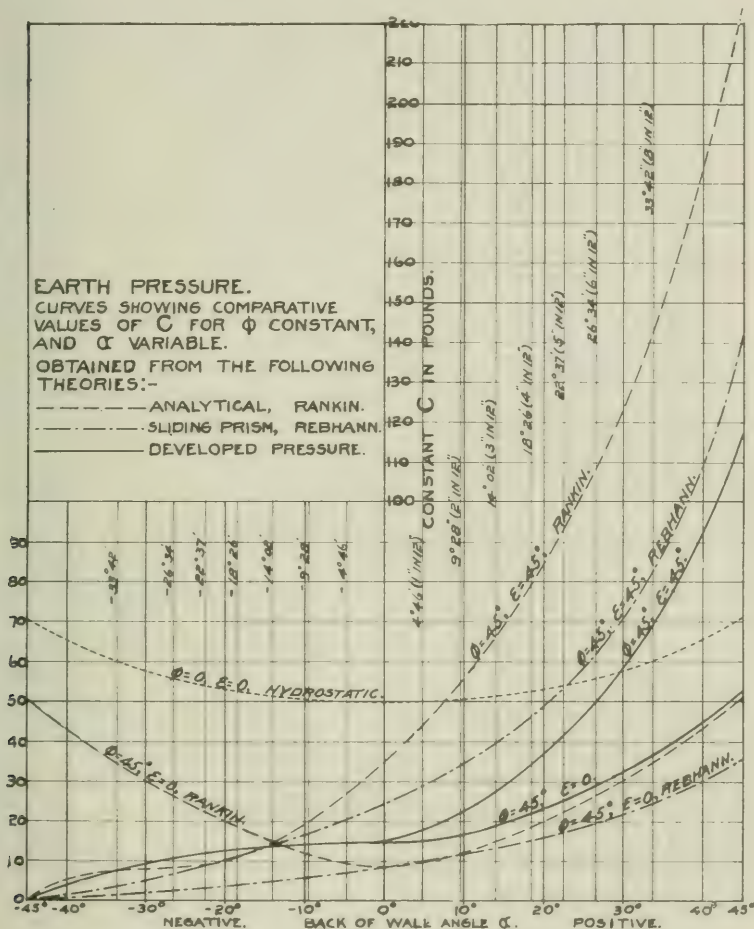


Fig. 4. Curves for  $\phi = 45^\circ$ ,  $\epsilon = 0$  and  $45^\circ$ .

As the reduction in pressure should be most rapid as the negative back batter,  $-a$ , approaches coincidence with the angle of repose (equal to the complement of  $\phi$ ) or limit, we should expect the curve for these values of  $C$  to be convex upward, instead of downward as obtained from Rebhann.

Fig. 5 shows curves platted from values of  $C$  for  $\phi = 33^\circ 42'$ , and  $\epsilon = 0^\circ, 33^\circ 42'$  and  $45^\circ$ . While the natural slope and surcharge of  $1\frac{1}{2}$  to 1 (angle  $= 33^\circ 42'$ ) are the most commonly met with, Rankine and Rebhann show poor agreement. For  $\phi = 33^\circ 42'$  and  $\epsilon = \phi$ , Rankine gives excessively high values. For  $\phi = 33^\circ 42'$  and  $\epsilon = 45^\circ$ , Rebhann gives excessively high values, and when the negative value of  $a = 9^\circ 28'$  is reached, a complete break-down occurs, as  $C$  begins to increase instead of continuing to decrease. With  $\phi = 33^\circ 42'$  and  $\epsilon = 0^\circ$ , Rankine gives the usual break-down for negative values of  $a$ .

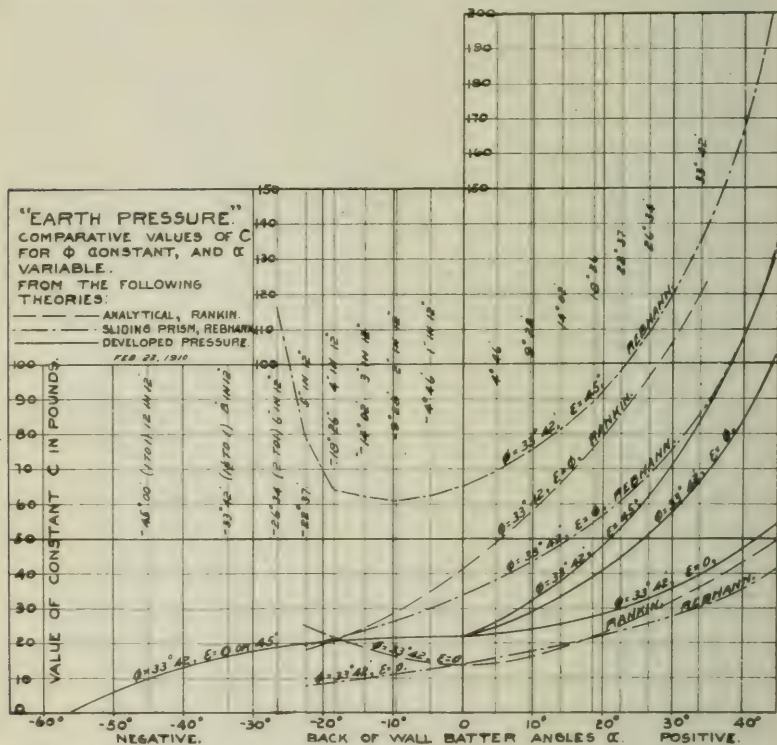


Fig. 5. Values of  $C$  for  $\phi = 33^\circ 42'$ , and  $\epsilon = 0, 33^\circ 42'$  and  $45^\circ$ .

In Fig. 6 is shown the curves obtained by plating the values of  $C$  for  $\phi = 9^\circ 28'$  (slope 6 to 1), and  $\epsilon = 0, 9^\circ 28'$  and  $33^\circ 42'$  respectively. The curve for hydrostatic pressure ( $\phi = 0^\circ$ ) is platted here for comparison. For  $\phi = 9^\circ 28'$  and  $\epsilon = 0$ , Rankine and Rebhann agree fairly well for positive values of  $a$ , both coinciding at  $a = 0^\circ$  and  $45^\circ$ . Rebhann gives the larger intermediate values. For negative values of  $a$  Rankine gives values which increase with the negative increase while they should

decrease. Rebhann gives a decrease in the values of  $C$  until  $a = -22^\circ 37'$  is reached; then a slight increase is given up to  $a = -33^\circ 42'$ ; after which they decrease, reaching zero when the value of  $-a$  = the complement of the angle of repose  $\phi$ . With  $\phi = 9^\circ 28'$  and  $\epsilon = 9^\circ 28'$  the two theories give values for

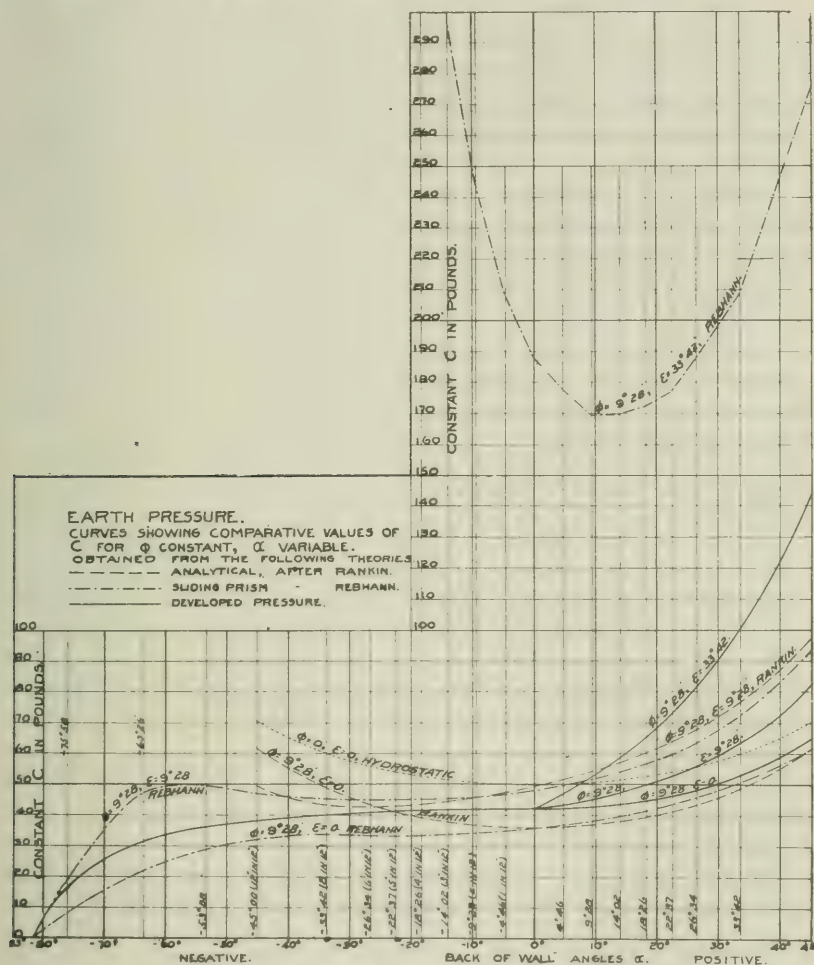


Fig. 6. Platted Values for  $\phi = 9^\circ 28'$ ,  $\epsilon = 0, 9^\circ 28',$  and  $33^\circ 42'$ .

$C$  that agree fairly well for  $a$  positive. For  $a$  negative, Rankine shows a decrease until  $a = -26^\circ 34'$  is reached, after which an increase takes place. Rebhann gives a decrease for negative  $a$  until  $-18^\circ 26'$  is reached, and they remain almost constant up to  $-38^\circ 40'$ . The values of  $C$  then increase until  $-57^\circ$  is reached,

when they rapidly decrease, reaching zero at  $\alpha = -80^\circ 32'$  = complement of  $\phi$ . These improbable negative values are given only to show the behavior of these formulae in reaching the limit.

#### ANGLE OF SURCHARGE $\epsilon$ GREATER THAN ANGLE OF REPOSE $\phi$ .

The most notable deficiency in one theory and the utter break-down of the other, is where the angle of surcharge  $\epsilon$  is greater than the angle of repose  $\phi$ . Rankine's formula gives no results whatever for those conditions, while Rebhann's graphics breaks down completely. Rebhann's break-down is most strikingly shown in Fig. 6, where the values of  $C$  for  $\phi = 9^\circ 28'$  and  $\epsilon = 33^\circ 42'$  are platted. Also in almost as marked degree in Fig. 5 for  $\phi = 33^\circ 42'$  and  $\epsilon = 45^\circ$ . In both cases the values are excessively high. For  $\phi = 9^\circ 28'$  and  $\epsilon = 33^\circ 42'$  the lowest value of  $C$  is given when  $\alpha = +9^\circ 28'$  and equal 169.6 lb. Instead of continuing to decrease to  $\alpha = 0$  and throughout the increased negative values of  $\alpha$ , a very rapid increase takes place reaching the enormous amount of 677 lb. for  $\alpha = -22^\circ 37'$ ; while hydrostatic pressure only amounts to 54.2 lb. The sketch of Rebhann's graphics from which the above values were derived is shown in Fig. 9.

The failures of Rankine and Rebhann under conditions of angle of surcharge  $\epsilon$  greater than the angle of repose  $\phi$  are very important for the following reasons:

1st. It is not uncommon to have a bed of sand, gravel, or stiff clay overlying a stratum or bed of very soft material which is penetrated by the excavation. With good, firm material above and below such a stratum, the pressure developed by the flow of the soft material, caused by the superimposed load and high surcharge (over the vertical projection of the back of wall batter) should be considered as giving the amount to be taken care of.

2d. With a material such as plastic clay the angle of repose for moderate heights may be as much as ninety degrees. At a great enough depth, however, the squeeze is developed and there results a flow in any direction where full resistance is not encountered. It will even heave vertically from the bottom of a pit. That is only a condition where the same material will hold a greater surcharge than the angle of repose or flow at considerable depth. It is probably owing to the cohesion of nearly all materials used in fills that more wall failures have not occurred, where theoretically they should have failed. On account of the cohesion, as well as the friction of the material, to be overcome before an active lateral pressure can be developed, the point of application of the resultant pressure is probably lower than one-third the height of fill  $h$ . That being the case the overturning moment would be less than usually computed.

# THE DEVELOPED PRESSURE THEORY.

On account of the great variation and lack of agreement between the analytical theory of Rankine, and the sliding prism theory as treated by Rebhann, and their break-downs, the author was led to consider *earth pressure* from an entirely different point of view.

The values obtained from the formula for *hydrostatic pressure* are considered to be beyond question. That being the case, the author was led to try out results by working with the hydrostatic pressure as a base from which to obtain all other values, corresponding to the different assumed angles of repose. Under that conception he treated the angle of repose as the angle at which flow would take place, or the *angle of flow*. Possibly another conception to take would be to treat it as the *angle of resistance to flow*, when referred to the horizontal or the angle of flow of a fluid. In fluids the pressure developed by gravity is transmitted equally in all directions. If in any case the substance is considered as losing part of its fluidity, there would then be a certain resistance to flow. If the angle of the resistance is expressed by the slope ratio or the angle  $\phi$ , then the sine of  $\phi$  may be considered as the amount of the resistance. Then we would consider the hydrostatic pressure reduced by the sine of  $\phi$  into the hydrostatic pressure. Hydrostatic pressure  $E = \frac{h^2 \gamma}{2}$ , in which  $h$  equals the height, and  $\gamma$  the weight of the fluid retained.

## FORMULAE FOR DEVELOPED PRESSURE THEORY.

1st. For Positive Values of  $a$  (back batter away from the fill).

For a substance having an angle of resistance to flow  $\phi$ , the formula would become

$$E = \frac{h^2 \gamma}{2} - \frac{h^2 \gamma}{2} \sin \phi = \frac{h^2 \gamma}{2} (1 - \sin \phi), \text{ when } a = 0.$$

When  $E$  is the pressure against a vertical plane alone and has no vertical component it may be represented by  $P$ .

The values of  $E$  at the limiting values of  $\phi$  are as follows:

$$\phi = 0, E = \frac{h^2 \gamma}{2} (1 - \sin \phi) = \frac{h^2 \gamma}{2} (1 - \sin 0^\circ)$$

$$= \frac{h^2 \gamma}{2} (1 - 0) = \frac{h^2 \gamma}{2} \text{ hydrostatic pressure.}$$

$$\phi = 90, E = \frac{h^2 \gamma}{2} (1 - \sin \phi) = \frac{h^2 \gamma}{2} (1 - \sin 90^\circ)$$

$$= \frac{h^2 \gamma}{2} (1 - 1) = \frac{h^2 \gamma}{2} (0) = 0.$$

For the intermediate value of  $\phi$  we have  $\frac{0 + 90}{2} = 45^\circ$ , when

$$\phi = 45^\circ, E = \frac{h^2 \gamma}{2} (1 - \sin \phi) = \frac{h^2 \gamma}{2} (1 - \sin 45^\circ)$$

$$= \frac{h^2 \gamma}{2} (1 - .707) = \frac{h^2 \gamma}{2} .293. \quad \text{In other words, the intermediate}$$

value of  $\phi$  gives a value for  $E$  which is a little over one-quarter that given for  $\phi = 0^\circ$  making  $E$  the maximum. The increase in the value of  $E$  ( $= C$ ) is almost inversely proportional to the square of decrease of  $\phi$  from the value ( $90^\circ$ ), giving the lower limit, as by the above formulae.

For back of wall batter  $\alpha$  positive (sloping away from the fill), and  $\epsilon = 0^\circ$ , the formula becomes:

$$E = \sqrt{\left[ \frac{h^2 \gamma}{2} (1 - \sin \phi) \right]^2 + W_c^2}, \quad W_c = \frac{h^2 \tan \alpha \gamma}{2}$$

$=$  the weight of the earth wedge carried on the vertical projection of the back batter of the wall.

In Fig. 7 is given the dimensions by which the area of the earth wedge carried over the back of wall batter may be determined. The larger diagram was originally drawn to scale with the height  $h$  as unity, and the results checked with trigonometrical formula. Referring to the sketch at the top of the diagram the formula for obtaining the area of the earth wedges  $A B L$  or  $A B S$  are as follows:

$$B L = A L \tan \alpha = h \tan \alpha.$$

$$\text{Area } A B L = \frac{B L \times h}{2} = \frac{h \tan \alpha h}{2} = \frac{h^2 \tan \alpha}{2}.$$

$$S L = B L \tan \epsilon = h \tan \alpha \tan \epsilon.$$

$$S A = h + S L = h + h \tan \alpha \tan \epsilon = h (1 + \tan \alpha \tan \epsilon).$$

$$\text{Area } A B S = \frac{B L \times S A}{2} = \frac{h \tan \alpha h (1 + \tan \alpha \tan \epsilon)}{2}$$

$$= \frac{h^2 (\tan \alpha + \tan^2 \alpha \tan \epsilon)}{2}$$

$$\text{Weight of } A S B = W_c = \frac{\gamma h^2 (\tan \alpha + \tan^2 \alpha \tan \epsilon)}{2}$$

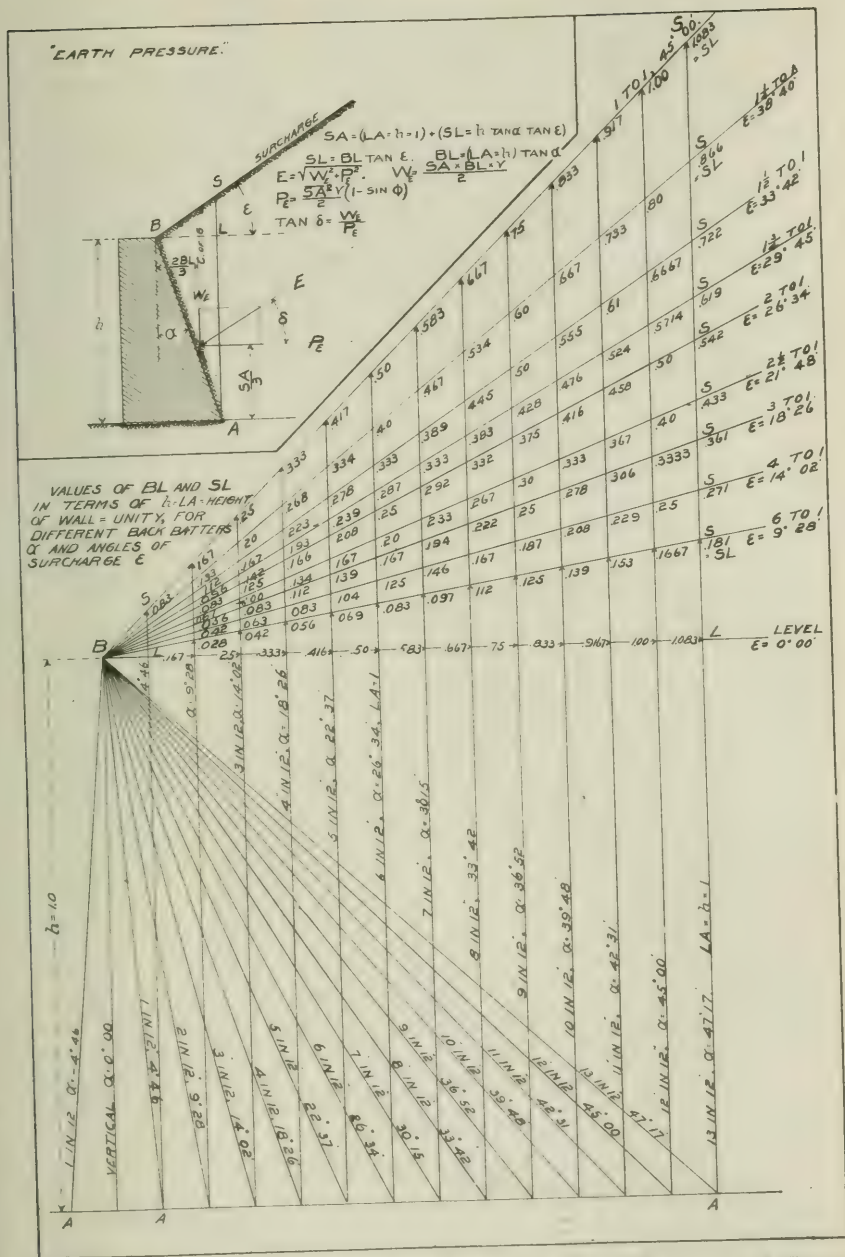


Fig. 7. Surcharge Heights and Back of Wall Batter and Surcharge Triangle Dimensions.

HEIGHTS $h_e$ AND AREAS $A_u$ OF EARTH WEDGE BACK OF WALL FOR DIFFERENT DEGREES OF SURCHARGE $\epsilon$ AND BACK OF WALL BATTERS $\alpha$ , BASED ON HEIGHT OF WALL $h$ EQUAL UNITY.			BACK OF WALL BATTERS AND ANGLE OF INCLINATION WITH THE VERTICAL $\alpha$ .																SURFACE SLOPE OR SURCHARGE ANGLE $\epsilon$																
SURFACE SLOPE OR SURCHARGE ANGLE $\epsilon$	VERTICAL	SURCHARGE	1° IN 12°		2° IN 12°		3° IN 12°		4° IN 12°		5° IN 12°		6° IN 12°		7° IN 12°		8° IN 12°		9° IN 12°		10° IN 12°		11° IN 12°		12° IN 12°		13° IN 12°		14° IN 12°		15° IN 12°		RATIO OF BASE TO HEIGHT		
			$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$	$h_e$	$A_u$			
45° 00'	0° 00'	0° 46'	1.00	.000	1.08	.045	1.17	.087	1.25	.156	1.33	.222	1.42	.295	1.50	.375	1.59	.462	1.67	.556	1.75	.656	1.83	.764	1.92	.879	2.00	.000	2.09	1.100	2.17	.863	225	1405	1 TO 1
38° 40'	0° 00'	0° 46'	1.07	.044	1.15	.054	1.24	.107	1.33	.278	1.40	.350	1.47	.428	1.53	.511	1.60	.600	1.67	.695	1.73	.794	1.89	.900	1.97	1.010	1.93	.187	1.010	2.00	1.650	1.1 TO 1			
33° 45'	0° 00'	0° 46'	1.05	.044	1.11	.053	1.17	.106	1.22	.204	1.28	.266	1.33	.333	1.39	.405	1.45	.482	1.51	.563	1.58	.648	1.61	.739	1.67	.832	1.72	.984	1.67	.923	1.65	1.442	1.1 TO 1		
29° 45'	0° 00'	0° 46'	1.03	.044	1.09	.051	1.14	.103	1.19	.195	1.24	.258	1.29	.321	1.33	.352	1.38	.460	1.43	.535	1.48	.615	1.52	.687	1.57	.766	1.62	.923	1.67	.873	1.65	1.421	1.1 TO 1		
26° 34'	0° 00'	0° 46'	1.02	.043	1.08	.050	1.12	.102	1.17	.194	1.21	.252	1.25	.319	1.29	.377	1.33	.445	1.40	.516	1.42	.590	1.49	.668	1.50	.750	1.54	.834	1.58	.823	1.62	1.415	1.1 TO 1		
21° 48'	0° 00'	0° 46'	1.03	.043	1.07	.050	1.10	.102	1.13	.189	1.17	.243	1.20	.300	1.23	.364	1.27	.422	1.30	.487	1.33	.556	1.37	.626	1.40	.700	1.43	.771	1.47	.855	1.52	1.405	1.1 TO 1		
18° 26'	0° 00'	0° 46'	1.03	.043	1.06	.050	1.08	.103	1.11	.185	1.14	.237	1.17	.292	1.19	.349	1.22	.407	1.25	.469	1.28	.533	1.31	.598	1.33	.667	1.36	.736	1.39	.809	1.42	1.395	1.1 TO 1		
14° 02'	0° 00'	0° 46'	1.02	.043	1.04	.047	1.06	.103	1.08	.181	1.10	.230	1.13	.281	1.15	.334	1.17	.389	1.19	.445	1.21	.504	1.23	.563	1.25	.625	1.27	.687	1.29	.753	1.31	1.382	1.1 TO 1		
9° 28'	0° 00'	0° 46'	1.01	.042	1.03	.046	1.04	.103	1.06	.176	1.07	.223	1.08	.271	1.10	.320	1.11	.371	1.12	.423	1.14	.465	1.15	.529	1.17	.583	1.19	.638	1.19	.696	1.21	1.355	1.1 TO 1		
4° 46'	0° 00'	0° 46'	1.00	.042	1.01	.044	1.02	.103	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.28
LEVEL	0° 00'	0° 46'	1.00	.042	1.00	.043	1.00	.125	1.00	.150	1.00	.175	1.00	.200	1.00	.225	1.00	.250	1.00	.275	1.00	.300	1.00	.325	1.00	.350	1.00	.375	1.00	.400	1.00	.425	1.00	.450	1.00

THE EQUAL AREA OF TRIANGLE  $ABS = SA \cdot BL + 2 \cdot \frac{1}{2} \cdot BL \cdot 2$ .

THE EQUAL HEIGHTS FROM THE BOTTOM OF THE EACH BATTER OF WALL TO THE POINT WHERE ITS VERTICAL PROJECTION INTERSECTS THE SURFACE OF THE EARTH ON BENCHING.

$h_e = SA \cdot SL \cdot LA \cdot h = h \cdot \tan \alpha \cdot \tan \epsilon \cdot h \cdot (1 + \tan \alpha \cdot \tan \epsilon)$

$AS \cdot h_e \cdot BL = 2 \cdot h \cdot (1 + \tan \alpha \cdot \tan \epsilon) (BL \cdot h \cdot \tan \alpha) = 2 \cdot h \cdot \tan \alpha \cdot \tan \epsilon \cdot h \cdot \tan \alpha \cdot \tan \epsilon \cdot h$

TO OBTAIN THE HEIGHT  $h_e$  FOR ANY HEIGHT OF WALL  $h$  MULTIPLY  $h$  BY THE VALUE OF  $h_e$  FROM THE TABLE FOR THE GIVEN VALUES OF  $\alpha$  AND  $\epsilon$  BY  $h$ .

FOR EXAMPLE FOR  $h = 20$ ,  $\alpha = 22^\circ 37'$  AND  $\epsilon = 35^\circ 42'$ . FROM THE TABLE  $h_e$  IS GIVEN AS 128.  $h_e \cdot (h_e \cdot \text{CONSTANT}) h = 128 \cdot 20 = 2560$ . BY  $h$  TO OBTAIN THE AREA  $A_u$  FOR ANY HEIGHT OF WALL MULTIPLY  $A_u$  OF THE TABLE FOR THE GIVEN VALUES OF  $\alpha$  AND  $\epsilon$  BY THE SQUARE OF THE HEIGHT  $h$ .  $A_u = \frac{1}{2} A_u$  FOR VALUES OF  $\alpha$  AND  $\epsilon$  AS ABOVE  $A_u = 266$ . HENCE FOR  $h = 20$ ,  $A_u = 266 \cdot 20 = 5320$ .

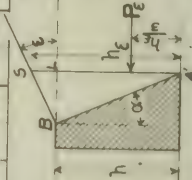


Fig. 7a. Tabulation of Computed Values of  $h_e$  Corresponding to Height SA of Fig. 7.

Also Area  $A_u$  Corresponding to Triangle BAS of Fig. 7.

The horizontal earth pressure  $P_e$  is taken for the full height

$S A$ , and equals  $\frac{\gamma}{2} (h [1 + \tan a \tan \epsilon])^2 (1 - \sin \phi)$ .

With surcharge and back of wall batter away from the fill,

$$E = \sqrt{P_e^2 + W_e^2} =$$

$$\sqrt{\left[ \frac{\gamma (h [1 + \tan a \tan \epsilon])^2 (1 - \sin \phi)}{2} \right]^2 + \left[ \frac{\gamma h^2 (\tan a + \tan^2 a \tan \epsilon)}{2} \right]^2}$$

The assumed point of application of  $P_e$  is at  $\frac{1}{3} S A = \frac{1}{3} h$  from the bottom.

#### DIRECTION OF EARTH PRESSURES.

The direction of the resultant earth pressure  $E$  with the

horizontal equals the angle  $\delta$ , and  $\tan \delta = \frac{W_e}{P}$ .

The earth pressure  $P$  is considered as acting only in a horizontal direction whether the wall carries a surcharge or not. When a mass of earth is either confined in a bin or surrounded by a mass of the same material, and indefinite in extent, the developed pressure producing squeeze, to be in equilibrium, must act and react on the particles within the mass. Consequently the net resultant of the squeeze will be at right angles to the force of gravity.

The case of material simply confined in a bin should not be confused, however, with the case in which material is withdrawn from the bottom. In the latter case, as soon as material is withdrawn from the bottom, friction is developed against the sides of the bin and the whole case is thereby modified.

#### WHERE SURCHARGE GIVES NO ADDED PRESSURE.

For a negative back of wall batter as well as for vertical back, a surcharge fill is not considered as giving any more pressure than if it ran off level or even sloped down away from the back of the wall. To illustrate, take Fig. 8, which represents a bin 40 ft. deep and 10 ft. square. For hydrostatic pressure the amount is the same, whether the fluid pressing against the side of the bin extends back from the face one foot or is of indefinite extent. The same should hold true within certain limits for granular and semiplastic substances. With a bin of the size shown and filled with a granular mass possessing little or no cohesion and incompressible, but having sufficient friction between the particles to stand at an angle of repose of  $45^\circ$ , there

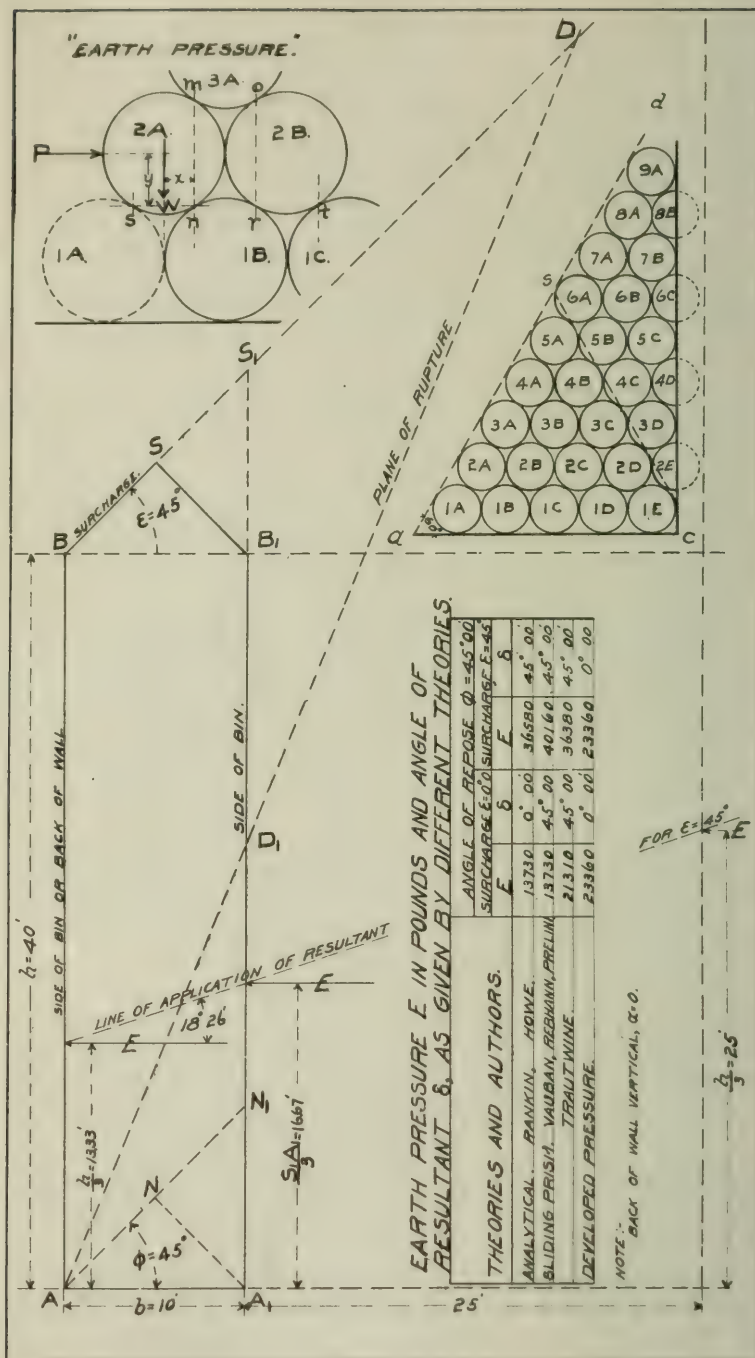


Fig. 8. Effect of Surchage on Bins and Walls.

is little reason to believe there would be any more pressure on the side A B with a surcharged slope than with a level top. In the upper right-hand corner of Fig. 8 is sketched what we will term a pile of cylinders, marked 1A—1E, 1A—9A, etc. A common example is the piling of barrels. When piled as shown they will stand with a natural slope of  $60^\circ$ , and are held in this position by friction alone, as there is manifestly no cohesion. If the cylinders and the plane a c, on which they rest, were to lose all friction they would sink to the level of 1 A, 1 B, etc. As long as the angle of friction between cylinders in contact is greater than  $30^\circ$  the cylinders will remain in equilibrium. (The angle which the tangent passing through the points of contact of the cylinders makes with the horizontal is  $30^\circ$ .)

To show that the surcharge of a slope should not increase the horizontal pressure against a vertical surface, consider the cylinders 1 A, 2 A, 3 A, 1 B and 2 B of a d c. While 1 A evidently holds the whole tier 2 A, 3 A, 4 A—9 A in position, it does not carry any more weight or thrust than if only 1 A, 2 A and 2 B were considered. 1 A and 1 B carry 2 A with points of contact or support at *s* and *n*. (See enlarged sketch of cylinders at upper left-hand corner.) Remove the cylinder 1 A, then to maintain 2 A in position and equilibrium, substitute a horizontal force *P* acting through the center of 2 A. Then 2 A is maintained in position and equilibrium by *P* and the weight *W*, acting through their respective lever arms, with *n* the point of contact as the center of moments. Total moments about *n* =

$$0 = P y - W x. \quad \text{From which } P = \frac{W x}{y}. \quad \text{But 2 A carries one-half}$$

the weight of 3 A applied at their point of contact *m*. By construction, *m* is vertically above *n*. Therefore the weight from 3 A applied at *m* will pass through the point of support *n*. As *n* is the center of moments for 2 A, the weight from 3 A and passing through *n* will not disturb the equilibrium of 2 A already established. The horizontal thrust *P* will not be increased by the added weight at the point of contact, so long as the angle of friction between the surfaces is greater than  $30^\circ$ . The other half of the weight of 3 A is carried by 2 B from the point of contact *o* and passed on to *r* without disturbing the equilibrium of 2 B. Thus it is seen that the cylinders above do not disturb the equilibrium or produce an added horizontal thrust in those below, but only contribute their weight to increase the vertical load. This is as it should be, for the particles on a natural slope to contribute an added horizontal thrust to those below, would imply an arching effect which does not exist. In other words, if arching of that kind took place, we would have the anomaly of the toe of the natural slope of an embankment carrying a

load greater than the weight of the material in the vertical projection above.

Returning to the bin  $A B B_1 A_1$  of Fig. 8. Suppose a prism  $A N A_1$  is piled in the bottom of the bin. As the toes of the slopes only reach to  $A$  and  $A_1$  there is no pressure developed in the sides  $A B$  or  $A_1 B_1$ . If a plane is passed vertically through  $N$ , however, we should expect to get the full developed horizontal pressure for the vertical height of  $N$  above the base  $A A_1$ . Compare this with the side  $c d$  of the pile of cylinders. The horizontal thrust from  $2 E$  is no more with all of the cylinders above in position than it is when they are removed. The only cylinders producing horizontal thrust on the side  $c d$  are  $2 E$ ,  $4 D$ ,  $6 C$  and  $8 B$ . If now the bin is filled up to the level of  $N$ , the pressure should be the same on the side of the bin  $A B$  as on the vertical plane passing through  $N$ . In other words, the horizontal pressure against any vertical plane passed through the level fill of the height  $N$  should be the same as against the side  $A B$ . The resultant of the developed pressure within the mass should be at right angles to the force of gravity.

To take still another view. Suppose the bin is filled to the level of  $N$  and then gradually removed from one side, say first to the slope  $A_1 N$ . Then continue the removal until the slope leaves the side  $A B$  at the level of  $N$ . At what point can we say the pressure against the side  $A B$  began to be less than when the bin was full up to the level  $N$ ? According to the sliding prism theory it should be when the line  $A D$  or plane of rupture is reached. But in reality has the plane of rupture anything to do with the development of horizontal pressure? Must we conclude that a bin must be wide enough for the plane of rupture  $A D$  to pass out before reaching or intersecting the side  $A_1 B_1$  before the full pressure of the retained material can be developed against the side  $A B$ ? Under that conception what is the character of the pressure developed against the side  $A_1 B_1$ ? The assumptions of that theory seem at least unusual, but still do not give as great values for surcharge as given by Rankine.

In the lower right-hand corner is given a table showing the values of the earth pressure  $E$  and the angle  $\delta$  which the resultant makes with the horizontal. The results are from Rankine, Rebhann, Trautwine, and the developed pressure theory. The assumptions are  $h = 40$  ft., side  $A A_1 = 10$  ft.,  $\gamma = 100$  lb. per cu. ft.,  $\phi = 45^\circ$ ,  $\alpha = 0^\circ$ , and  $\epsilon = 0^\circ$  or level in one case and  $\phi$  or  $45^\circ$  in the other. It will be noted that both Rankine and Rebhann give about three times, and Trautwine nearly twice the amount of pressure  $E$ , for surcharge over what they give without. The value of  $E$  by the developed pressure theory is considered the same either with or without surcharge and is not far from a mean of the values given by the other theories when  $\epsilon = 0^\circ$  and  $\epsilon = 45^\circ$ . It should be noted also that

there is little agreement between the different theories for the value of the angle  $\delta$  which the resultant makes with the horizontal.

2d. *For Negative Values of  $a$  (back batter toward the fill).*

With back batter toward the fill or  $a$  negative, the formula employed for obtaining the earth pressure is:

$$E = \frac{h^2\gamma}{2} \left( 1 - \frac{\sin. \phi}{\cos. a} \right)$$

The values of  $E$  at the limits of  $\phi$  and  $a$  are:

$$\begin{aligned} \text{for } \phi = 0^\circ \text{ and } a = 0^\circ, E &= \frac{h^2\gamma}{2} \left( 1 - \frac{\sin. \phi}{\cos. a} \right) = \frac{h^2\gamma}{2} \left( 1 - \frac{\sin. 0^\circ}{\cos. 0^\circ} \right) \\ &= \frac{h^2\gamma}{2} (1 - 0) = \frac{h^2\gamma}{2} = \text{hydrostatic pressure.} \end{aligned}$$

$$\begin{aligned} \text{for } \phi = 90^\circ \text{ and } a = 0^\circ, E &= \frac{h^2\gamma}{2} \left( 1 - \frac{\sin. \phi}{\cos. a} \right) = \frac{h^2\gamma}{2} \left( 1 - \frac{\sin. 90^\circ}{\cos. 0^\circ} \right) \\ &= \frac{h^2\gamma}{2} \left( 1 - \frac{1}{1} \right) = 0 \end{aligned}$$

For  $a =$  the complement of  $\phi$  (or when the back batter coincides with the natural slope,  $a = 90^\circ - \phi$ ), then  $E =$

$$\begin{aligned} \frac{h^2\gamma}{2} \left( 1 - \frac{\sin. \phi}{\cos. |90^\circ - \phi|} \right) &= \frac{h^2\gamma}{2} \left( 1 - \frac{\sin. \phi}{(\cos. \text{complement } \phi = \sin. \phi)} \right) \\ &= \frac{h^2\gamma}{2} (1 - 1) = 0. \end{aligned}$$

VALUES OF  $C$ , DEVELOPED PRESSURE THEORY, COMPARED WITH THOSE FROM RANKINE AND REBHANN.

This second set of comparisons is made at the risk of some restatements.

Referring again to Figs. 2, 3, 4, 5, and 6, the values of  $C$  for the developed pressure theory are shown by the solid line; those from Rankine by dashes and Rebhann by a dot and dash.

In Fig. 2 the values for " $a = 0$ , and  $\epsilon = 0$  or  $\phi$ ," are greater than Rankine and Rebhann give for " $a = 0$ ,  $\epsilon = 0$ ," but are less than those given for " $a = 0$ ,  $\epsilon = \phi$ ." As previously stated, when  $a = 0$ , or is negative, a surcharged fill is not considered as giving any greater pressure than one without.

It will be noted that the values given by the developed

pressure theory are almost a mean of those given by Rankine and Rebhann under the extremes of  $\epsilon = 0$  and  $\phi$ . For  $\alpha = 33^\circ 42'$  and  $\epsilon = \phi$ , the developed pressure formulae give much lower values than the old theories, with one exception. For  $\phi =$  about  $55^\circ$  Rebhann crosses the solid line and gives lower values. That however is an evident break-down in Rebhann. The increase shown by the solid curve is about as we should expect. The increase in  $E$  (C) caused by the added load of the earth wedge with its surcharge is almost offset by the decrease in the horizontal pressure  $P$ , as the angle of repose  $\phi$  increases.

In Fig. 3 for the two groups of curves shown  $\alpha = -4^\circ 46'$  and  $-22^\circ 37'$ , with  $\epsilon = 0$  and  $\phi$ , the values for the developed

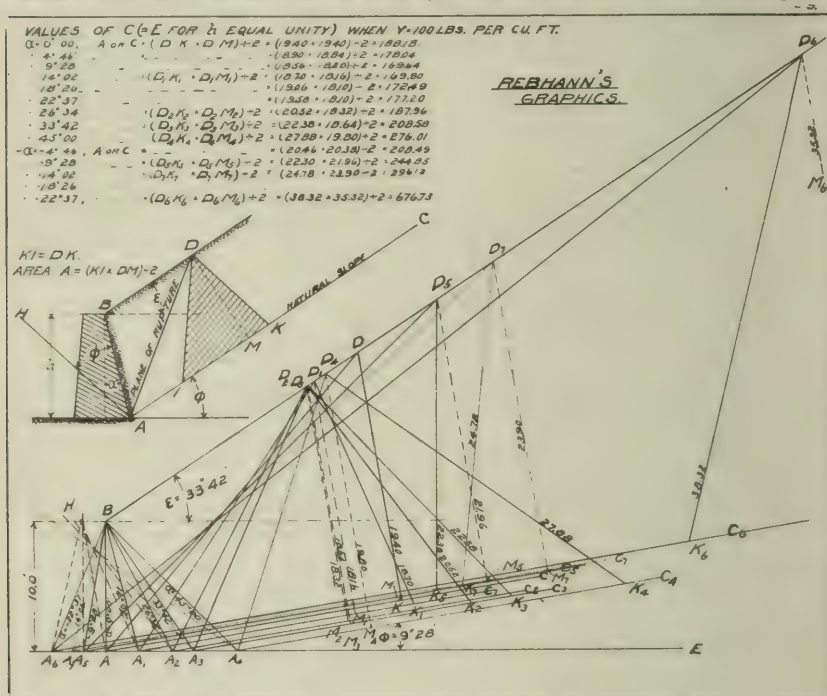


Fig. 9. Break-down for Surcharge Greater than the Angle of Repose.

pressure theory are almost a mean of those given by Rankine and Rebhann.

In Fig. 4 curves are given for  $\phi = 45^\circ$ , with  $\epsilon = 0^\circ$  and  $45^\circ$ . For  $\epsilon = 0$ , the developed pressure formula gives larger values than obtained from Rankine and Rebhann, but for  $\epsilon = 45^\circ$  the results are less, when  $\alpha$  is positive. When  $\alpha = 0$ , the two curves join, and continue with one value throughout for  $\alpha$  negative. Compare this with the break-down of Rankine and the very

low values of Rebhann for  $\epsilon = 0$ . Also note the solid curve is convex upward while Rebhann is convex downward.

In Fig. 5 is given curves for  $\phi = 33^\circ 42'$ , and  $\epsilon = 0, 33^\circ 42'$  and  $45^\circ$ . The three curves for  $a$  positive join at  $a = 0$ , and for negative  $a$  the curve is convex upward. Compare this with the very large values given for  $\epsilon = \phi$  by both Rankine and Rebhann, and the break-down of Rebhann for  $\epsilon = 45^\circ$ .

In Fig. 6 is given a group of curves for  $\phi = 9^\circ 28'$ , and  $\epsilon = 0, 9^\circ 28'$ , and  $33^\circ 42'$ . The same general characteristics are shown on comparison as seen in Figs. 4 and 5 except that Rebhann gives two curves convex upward for  $a$  negative. One of these is a complete break-down and the other a very close approach. Compare this also with the complete break-down of Rebhann for  $\epsilon = 33^\circ 42'$  as previously noted. The graphic sketch from which the Rebhann results were obtained is shown in Fig. 9. Neither Rankine's formula nor the graphics give any results for the condition where  $\epsilon$  is greater than  $\phi$ . As previously mentioned, the case of a heavy surcharge over a bed of soft material and the back batter away from the fill is one of the most important to provide for. The increased value of  $C$  ( $E$ ) comes both from the added height  $S L$  to  $h$  (Fig. 7) giving greater value to  $P$ , and the increased weight of the earth wedge  $A B S$  carried by the wall foundation.

A fact brought out by platting the results for the developed pressure theory is that no break-downs have been discovered so far, but the results are consistent throughout. There are no excessively high values given. For  $a$  negative, the curves are all convex upward and decrease most rapidly as the zero limit of  $C$  is approached. That feature is as we should expect. The equations are satisfied at the limits.

A complete set of values for  $C$  ( $= E$ ) have been worked out and tabulated for the developed pressure theory on the same basis of angles of repose  $\phi$ , surcharge  $\epsilon$ , and back of wall batter  $a$ , as was done for Rankine and Rebhann. Also a set of constants  $C$  for the horizontal pressure  $P$  for the heights given by the different surcharge angles and back of wall batters. These will possibly be published later, as well as other added data.

#### SUMMARY.

No attempt has been made to give a complete mathematical analysis or discussion of the formula used. The author can only repeat what has been said above. The results appear to be consistent and without any break-downs. That can not be said of the old formulae.

Until such time as a set of tests shall have been made on a large scale to verify or disprove any theory, we are only justified in using such theories as give the most rational and consistent results. Small model tests on a material possessing

any degree of cohesion are perhaps worse than useless. That is equally true of materials possessing both cohesion and friction between the particles of its composition. Owing to the fact that nearly all retained earth possesses both cohesion and friction, it is quite probable that the full resultant earth pressure is developed at a point lower than one-third the height. As an instance to illustrate the point at issue, observe the caving of an ordinary bank. For several feet at the top the slope is almost invariably vertical.

It is to be hoped that tests may soon be made on a large scale to give as near as may be, by exact experimental data, the true values for earth pressure.

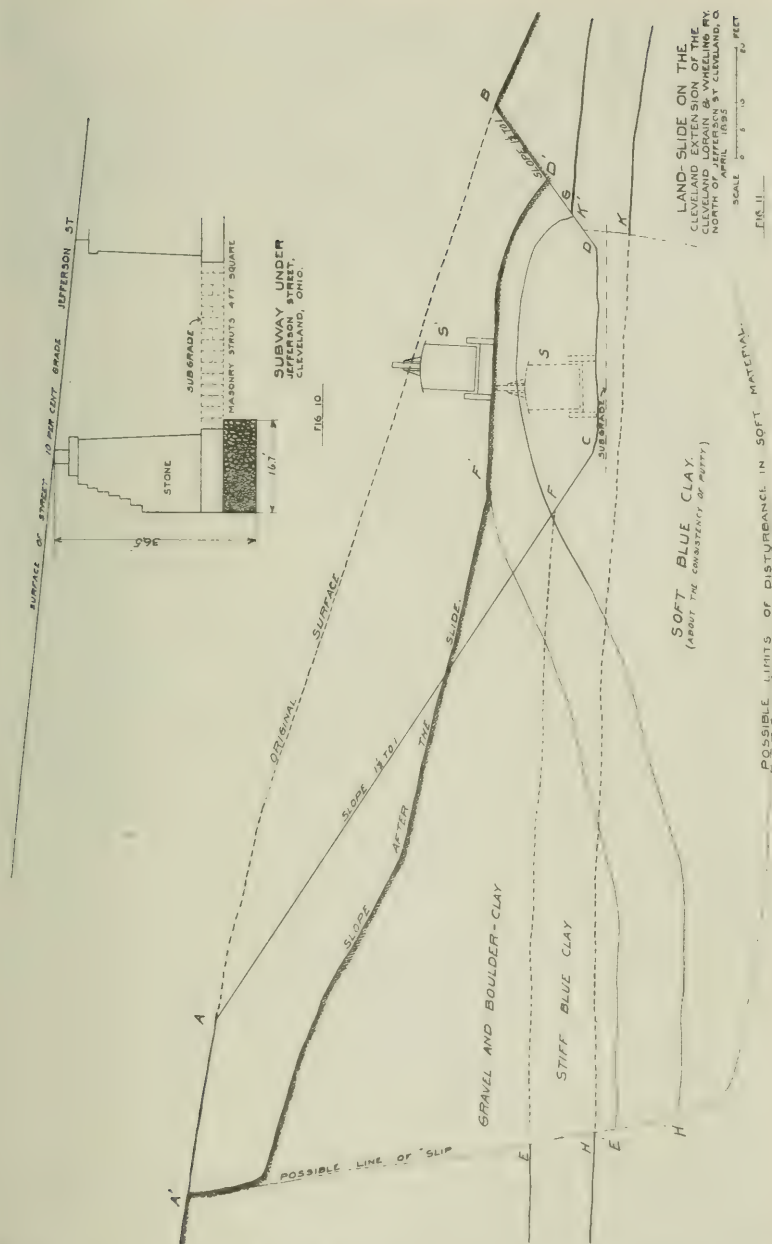
In the meantime the author respectfully presents the theory based on the assumption that "the horizontal pressure is equal to hydrostatic pressure, diminished by the sine of the angle of resistance to flow ( $= \phi =$  the angle of repose) into the hydrostatic pressure," or what I have chosen to call the developed pressure theory, for the consideration of the engineering profession.

Before dismissing the subject, which has so far been treated wholly on theory, it may be of interest to give an account of a landslide which took place on some work with which the author was connected some years ago.

In 1894-5 the Cleveland, Lorain and Wheeling Railroad Company (now part of the Baltimore and Ohio system) built an extension into the city of Cleveland, Ohio. The Cleveland entrance was through the valley of the Cuyahoga river. For some distance before reaching its junction with the Erie Railroad it ran along the bluffs west of the river. At Jefferson street the line was thrown into the hill far enough to get an under crossing. The grade of Jefferson street is ten per cent.

In making the side hill cut a short distance south of the crossing, blue clay was penetrated and slides began to develop. On reaching Jefferson street it was found it would be impossible to carry the open cut across the street as originally intended.

The excavation for the uphill abutment was then started and carried down by sheet piling the pit. The depth from street grade to foundation was about 36.5 ft., and from subgrade of track 10 ft. The timbering for the pit was 8 in. by 8 in. pine for struts and string pieces, spaced about 8 ft. Before the full depth of excavation was reached it was found necessary to put in a second set of timbers, and eventually a third set. In many cases the pressure developed was sufficient to compress the ends of the struts into the string pieces of the first sets of timbers fully four inches and many of the struts were broken. The upper part of the pit was through boulder clay and gravel. For some distance above subgrade of the track, hard blue clay was penetrated, while a little below subgrade a soft putty-like blue clay was encountered and formed the foundation bed.



Figs. 10 and 11. Land Slide from Steep Surcharge and "Flowing" Understrata.

As seen in Fig. 10, the section of the wall as built was very massive. The ratios of base to height were: neatwork, 0.52, and the footing, 0.44. To insure against the wall being pushed forward or overturned, stone struts 4 ft. by 4 ft. were built below grade, abutting against the footing of the downhill abutment. To prevent sliding of one course of masonry on the other, the courses were broken at intervals by keys of single stone, extending half their thickness in the course below and half in the course above. The wings, which were straight, were not at first provided with the struts. After a time the wings began to move forward and they had to be held in the same manner as the body of the wall.

About the time the uphill abutment was completed, and the excavation taken out from in front of it, and the excavation for some hundred feet north had nearly reached subgrade, a slip or landslide took place about as shown in Fig. 11. The top of the slope as shown at A was about 70 ft. above grade. The material penetrated by the cut is shown roughly in the figure. The cut as taken out, approximated the section shown by the line A C D B at a point about 200 ft. north of the abutment where the main slide took place. After the slide, the outline of the surface was about as shown by  $A^1 F^1 D^1$ . There was an almost vertical drop at  $A^1$  of something like 16 ft. At the same time there was an almost vertical lift in the bottom of the cut of nearly 20 ft. The steam shovel which was in the position S was lifted almost vertically to about the position  $S^1$ . The shear at  $A^1$  was about 30 ft. back from A. The geological formation was approximately as shown on Fig. 11. The upper portion for considerable depth was boulder clay and gravel. Then came a layer of stiff blue clay, underlaid by a bed of soft blue clay. The probable line of shear from the top of the bank is shown by the line  $A^1 E H E^1 H^1$ . The possible limits of disturbance in soft material is indicated by the line  $H^1 K K^1$ . The conditions were such that when the crust of hard material was cut through, the excess weight from the high portion of the bank  $A A^1$  induced flow in the soft underlying material and caused it to break through and rise in the bottom of the cut and take the position shown by line  $F^1 D^1$ . The strata of stiff clay designated by E F and H K would take the new position about as shown by  $E^1 F^1$  and  $H^1 K^1$ . The point of the reversal in movement would probably be back of F somewhat near where the lines are shown crossing.

As the sketch of the slide is made wholly from memory, some of the details are not so exactly reproduced. The general features were substantially as shown. The apparently remarkable feature of the occurrence was the fact that the movement was such as to lift the steam shovel for nearly twenty feet and leave it on an even keel.

The above, while at first thought appears a very unusual occurrence, is not so different from what we should expect after making a closer study of conditions. The conditions as shown in the above case are among those that are the most difficult to detect; it is also difficult to design structures that will safely resist the resultant forces.

Structures for retaining earth are among the most costly which the engineer is called upon to design and construct. In the broadest sense we are not getting as good and satisfactory results as should be obtained.

NOTE: The misspelling of the name Rankine, in the illustrations, occurred in the original drawings and could not be easily corrected.

### DISCUSSION.

*Mr. O. P. Chamberlain*, M. W. S. E. (Chairman): The paper before us is on a topic with which many of us are quite familiar in a practical way. Probably in no city in the country within the last ten or twelve years has there been more work done in the construction of retaining-walls than in and about Chicago. I presume many of the engineers who have handled this work have not gone very deeply into the theory of retaining-walls but have been guided by precedent. The author presents a new conception of the theory of the earth pressure on retaining-walls, which he designates as developed-pressure. The paper is an extremely interesting one and is especially creditable on account of its uniqueness and originality.

*Mr. Ernest McCullough*, M. W. S. E.: The paper by Mr. Mohler is interesting as being an opening shot in a battle to be waged on theories of earth-pressure pending comprehensive experiments on a large scale.

Regarding the theory of Professor Rankine, we are told nothing new. The distinguished author of that theory himself pointed out its limitations, but believed it would serve until proper experiments could be made. The graphical solution by Rebhann of the prism of maximum pressure appeared in 1871, but the work of Weyrauch, published in 1878, was so superior that Rebhann was forgotten. No prominent English or American author mentioned him until 1909, when his method appeared in Prelini's book.

For some years past the subject of earth-pressure has been considered as of little practical value—a mathematical recreation only for learned professors. Retaining-walls have been built from time immemorial, and few gravity walls have been built in which any pretense was made of considering theory. We see many strange and uneconomical sections as a result. The reason assigned for the failure of the wall illustrated is a case in point. This wall did not tip merely because the resultant passed too close to the toe, but in the picture is shown the cause. The ditch to drain the roadbed passes close to the wall, and no doubt the foundation has become so soft that the toe-pressure is excessive.

There are two reasons for requiring the resultant to pass through the middle-third: First, that the maximum pressure will not exceed twice the average, and, second, that there shall be no tension on the heel. It is very important that the pressure at the toe be kept well within the limits of pressure that the foundation soil will carry. This can be attained by making the base wide or by driving piles under the toe. Many draftsmen, and even chief engineers, have made drawings for extremely massive walls only to find them tipping after all. The remedy adopted is generally to increase the section, when the real cause for failure may be poor drainage of the roadbed, and supporting-piles the real remedy.

Generations of experience have shown that a rectangular wall with a thickness equal to one-third the height will do for average conditions if built of first-class masonry or concrete. This is to retain a fill level on top and flush with the top of the wall. For surcharged-walls make the base thickness one-third the height plus one. For extraordinary conditions, experience and study of good examples will lead to the adoption of a base wide enough to make the wall safe. An occasional failure is not fatal. Sir Benjamin Baker stated that for an engineer to claim he had no retaining-walls fail simply proved his inexperience and was no argument to show he possessed superior ability.

Vauban was able to save material in the walls he built by battering the front face and increasing the bottom width. For walls with a vertical back, equivalent sections, so far as stability is concerned, are obtained when the face batter-lines pass through a point one-ninth the height from the bottom; that is, all the walls have the same thickness at this point.

Poncelet deduced the following formula for trapezoidal walls with battered face, vertical back, and equal moment about the toe:

$$b' = b + \frac{1}{10} b''$$

in which  $b'$  = base of trapezoidal wall.

$b$  = base of rectangular wall.

$$b'' = \text{assumed base of battered face} = \frac{h}{\tan B}$$

$h$  = height of wall.

$B$  = inclination of face to the horizontal.

The accuracy increases with the inclination of the face.

I find myself unable to agree with Mr. Mohler on the question of surcharge. It seems reasonable to believe that an additional height of fill implies additional weight. If this be true, then there must be additional pressure. The toe of a slope having an angle equal to the angle of internal friction of the material, is assumed as starting from the foot of the wall. The wall is built to retain filling

placed on this slope. Cohesion in the material is uncertain and must be neglected. Friction alone can be considered, and the effect of friction is lessened if moisture is introduced into the mass, thus increasing the pressure. Assume a wall of sufficient weight and stability to retain a fill and be on the point of overturning. Cohesion of the material neglected, and friction alone being considered, there will be manifested a tendency toward readjustment of all particles above the angle of internal friction starting from the heel of the wall, if additional filling is provided, as in case of a surcharge.

The assumption of increased pressure against the wall because of surcharge is in agreement with common observation, the results of experiments and theoretical, or hypothetical, deductions. Returning again to the rectangular wall, the following rules of French engineers are useful for fixing the thickness when there is surcharge:

Let  $h'$  = height of surcharge above wall.

$h$  = height of wall.

$b$  = thickness.

then  $b = \frac{h}{3} + \frac{h'}{3}$ , if  $h'$  is less than  $\frac{h}{2}$

and  $b = \frac{h}{3} + \frac{h'}{15}$ , if  $h'$  is greater than  $\frac{h}{2}$

For values of  $h'$  in terms of  $h$  between 3 and 15, interpolations can be made. The base width or thickness having been fixed, the face may be battered by the rules already given and a saving in material effected.

For a typical rectangular wall having a thickness equal to one-third the height, the three fundamental formulæ are practically as follows:

$$\text{Horizontal thrust} = 16 h^2$$

$$\text{Overturning moment} = 5.4 h^3$$

$$\text{Resisting moment} = 11 h^3$$

the assumption being, a fill level with the top of the wall; the weight of the fill per cubic foot being 82% of the weight of the masonry; the factor of safety against overturning being 2+. The above formulæ were given by the late E. Sherman Gould in *Van Nostrand's Magazine*, March, 1883, Vol. XXVIII, page 204.

It is seldom that walls built today have much face-batter, the general rule being to make the face nearly vertical and slope the back. This throws the center of gravity well forward. All the earth resting on the rear projection of the wall adds weight, so the center of gravity of this earth wedge is found, and then the center of gravity of the compound section, a vertical being passed through it. The line of thrust is drawn through this vertical and from the point of intersection are plotted the thrust and the weight of the wall with weight of the earth wedge on the rear projection. Com-

pleting the diagram by drawing the resultant, the stability of the wall is determined.

The angle the resultant makes with the vertical depends upon the weight of the wall, the amount of thrust, and the angle of thrust. In the Coulomb theory of pressure of maximum wedge, no direction was originally indicated for the thrust. Later authorities variously made it horizontal or sometimes parallel with the slope of repose. Some men put it normal to the back of the wall, but for nearly fifty years the wedge of earth resting on the rear projections of the wall has been considered as adding weight and stability, the back surface being, therefore, considered as vertical. Professor Cain assumes the thrust as normal to a line representing the angle of friction between the wall and the earth fill, thus inclining the thrust downwards. Rankine assumed the thrust as parallel with the surface of the fill, so that with high surcharge it inclines downward considerably. The factor of safety is increased by assuming the thrust to act horizontally.

Experiments indicate that for low walls the thrust acts at about half the height and drops to about four-tenths the height as the height increases, until for walls exceeding 10 ft. the point of application is at one-third the height, as for a fluid.

A great many walls are built without any calculations being made to determine the amount of thrust or probable pressure on the toe. Some very poor sections go in merely because they look right and nothing is done to assure anyone that they are right. It takes but a few minutes to test the matter by the best information at hand, so this should not be neglected.

It is at this point the theories come in. The formula of Rankine gives considerably higher results than any other, so is more generally used today than the formulæ based on the theory of the maximum wedge. The fluid-pressure formulæ presented in the paper seem to be consistent between extremes, so it may be safely used. The fluid-pressure idea, however, is not new, and for nearly a century designers have used the formula for fluid-pressure. Coulomb's theorem was expressed by a formula in which

$w$  = weight of a cu. ft. of soil in lb.

$h$  = the height of the wall in feet.

$r$  = the angle of internal friction.

$s$  = the angle at which the effect of cohesion is lost.

$P$  = horizontal thrust in lb. against the wall.

then

$$P = \frac{wh^2}{2} \times \cot s \times \tan (s - r)$$

A fluid having no limiting angle of resistance, the formula becomes

$$P = \frac{w h^2}{2}$$

Coulomb's theorem showed that the wedge of maximum pressure has a face bisecting the angle made by the slope of repose with the vertical, so

$$P = \frac{w h^2}{2} \cot^2 s$$

$$\text{for } \cot s = \tan (s - r)$$

If we assume sand having a weight of 106 lb. per cu. ft. with an angle of internal friction, or slope of repose of  $30^\circ$ , the above expression reduces to

$$P = 16 h^2$$

one of the fundamental equations already given. This represents the horizontal thrust of a fluid weighing 32 lb. per cu. ft.

The thrust being applied at one-third the height, we have an overturning moment,

$$M_o = 16 h^2 \times \frac{h}{3} = 5.4 h^3$$

and for a factor of safety of 2 +, the resisting moment (neglecting fractions) is

$$M_R = 11 h^3$$

These equations may be proven in another way. It has been said that walls built for many generations have proven stable when the thickness is one-third the height with a rectangular section. Assume such a wall and then alter the form of the section so material can be saved without affecting the stability.

Let  $W$  = total weight of wall and earth wedge.

$P$  = horizontal thrust.

$b$  = width of base.

$i$  = intercept on base between resultant and vertical through center of gravity of compound section.

$h$  = height of wall.

then

$$W i = P \times \frac{h}{3}$$

In order that the maximum pressure be not more than twice the average, and that there be no tension at the heel, or back end of the footing,  $i$  cannot be greater than

$$\frac{b}{6}$$

If the moment of stability of the section is equivalent to

$$W i = P \times \frac{h}{3} = 5.4 h^3$$

the wall will be just on the point of overturning about the toe.

When there is surcharge, the typical rectangular wall may be assumed and the base broadened in accordance with the empirical rules already presented; calculations made for stability, and an equivalent fluid-pressure found, the thrust of course being horizontal.

For all retaining-walls having level fill, the thrust will be  

$$P = 16 h^2$$

applied at one-third the height and normal to a vertical dropped through the center of gravity of the compound section consisting of the wall and the earth wedge on the rear projection. Having the weight of the wall, and earth wedge acting vertically through the center of gravity, the resultant can be drawn and the maximum toe-pressure found.

A knowledge of the forces acting to overturn retaining-walls is important just now, for reinforced concrete walls are supplanting heavy gravity sections in many places. There is no precedent to guide designers, so theories of earth-pressure, long regarded as absorbing mathematical recreations, are coming again to light and we are on the threshold now of a mighty discussion. Dr. Baker and Professors Turneure and Maurer have called attention to the thrust of equivalent fluid-pressure, found by ascertaining the stability of standard walls evolved by generations of wall builders.

The reinforced-concrete wall is seldom more economical than a gravity wall for heights of less than 10 ft. At this height it is well to begin making comparisons, while for walls over 20 ft. in height the reinforced-concrete wall is said to show an economy in cost of about 25%. This is worth trying for, so this type of wall is going to be the wall of the future. To secure the greatest economy, the amount and direction of forces to be resisted must be known. Mr. Mohler has performed a good service in calling attention at the present time to the limitations of present accepted hypotheses. They should hardly be dignified by the term *theory* until proven by experiment. Experiments are needed on full size walls, for at present we have records only of experiments on small models with material without cohesion. Until proper experiments are made, however, the equivalent fluid-pressure method apparently satisfies requirements.

*Mr. Chamberlain:* Mr. McCullough spoke about one thing which I rather expected him to go into a little further. That was the matter of surcharge of a wall. Referring to Fig. 8, and the page following, the conclusion reached is that the horizontal thrust,  $P$ , will not be increased by the added weight at the point of contact, so long as the angle of friction between the surface is greater than  $30^\circ$ . I take exception to the demonstration shown there and the

conclusion drawn, which is that if a number of cylinders of uniform diameter are in equilibrium while the angle with the horizontal is  $60^\circ$ , a heterogeneous mass of earth would follow the same rule. The condition that exists there is due to the fact that these cylinders are of uniform diameter and that they are in close contact. If, for example, the lower line of cylinders had not been put in close contact, the whole mass would fall like a house of cards.

Another thing: It occurs to me that if we can prove, by using these cylinders, that there is no horizontal thrust, on the same hypothesis we would also prove that the surcharge of earth would stand at an angle of  $60^\circ$ , which of course is not true. The fact that these hexagons formed by circles placed in contact, or that cylinders placed in contact, maintain a position of equilibrium, does not prove by any means that thrust would not occur in a heterogeneous material which we know would not stand at an angle of  $60^\circ$ . In fact, we are very certain—there is no question in my mind at all—that a material which is surcharged over a retaining-wall does produce thrust on the wall. I think our old method of treating this is practically correct. Whether we can measure it exactly is another question.

*Mr. McCullough:* That is the way a great many reinforced-concrete walls are built these days, and it is the reason that the subject of earth-pressure is again becoming a live one. We have masonry now that will take tension and we do not have to depend upon gravity, because we figure on the weight there, to help us.

*Mr. W. H. Finley, M. W. S. E.:* I think we are all indebted to Mr. Mohler for the amount of work he has put upon this paper in developing the theories of the different authorities on retaining-walls. I believe, myself, that there are so many factors that we cannot control, entering into the pressures on a retaining-wall, it is very difficult to make any theoretical deduction.

One of the necessary things to do is to look after the foundation, and another is to be sure that the wall is well drained. With these conditions taken care of, I believe that almost any of the accepted methods of designing a retaining-wall will give satisfactory results. There is no doubt that the reinforced-concrete retaining-wall forms the very best solution of retaining earth-pressure. In the stone-masonry retaining-wall, it was just a question of providing a mass to resist the action of the earth. With the reinforced-concrete retaining-wall, we can and do have a material that will resist tension.

The preceding speakers, in drawing their sections of reinforced-concrete retaining-walls, all assumed that a toe can be put in front. This cannot always be done. On a street line, or on a party line, one must not project the toe of the wall beyond the line. There is no doubt, however, that in extending the base backwards and making use of the weight of the earth itself in helping to resist the over-

turning moment, we are getting nearer a correct and an economical solution than by any of the other methods. I have designed a few retaining-walls and have noticed a great many built in various sections, but do not know that I have ever yet seen one that actually failed—that actually tumbled over. Any number of them can be seen in this city and other places, where they have gone out of line, where they have been pushed over in varying amounts and then apparently reach a condition of equilibrium and never move afterwards.

Personally, I believe that more can be accomplished by being sure of the foundation and the drainage of the wall than by any mathematical deduction of earth-pressures. I believe the controlling factors are so hard to arrive at that one can never get a formula that will cover all cases; take, for instance, the city of Chicago, where sand is being used mostly for track-elevation. Sand is a material that is probably as near uniform as any that can be had, yet it will vary considerably, due to the amount of moisture in it, and it undoubtedly is very different from the earth that is usually piled up against a retaining-wall, as on railroad construction, where there is no choice but to use the material at hand, and it may be a mixture of soil, clay, and sand.

My advice would be, as I remarked before, to pay particular attention to the foundation and be sure that the wall is well drained.

*Mr. W. C. Armstrong, M. W. S. E.:* The subject of retaining-walls has been very attractive for mathematical experts, and I think there have been more worthless mathematics worked out on this subject than on any other that I know of, unless it be the methods of calculating earth-work. That used to be a favorite subject years ago.

I think the old rules for retaining walls are near enough correct. In looking over the diagrams in the paper Mr. Mohler has presented and considering the effects within the limits of practice, we do not find that the pressures from the various formulas differ very much. If we take a wall with a vertical back, without surcharge, and an angle of repose of  $1\frac{1}{2}$  to 1, they are almost identical. Now those are the usual conditions, and the results deduced from those conditions will give a formula that is near enough correct for any practical purpose. The only value of a formula in any case is to get uniformity in construction. We do not know whether the pressures we get from those formulas are correct or not. We never can know. I do not believe that any additional experiments, on a large scale or a small scale, would be of any benefit whatever, practically. The pressure that might exist against a wall at one time with the same material would be different at another time. Dry sand is different from wet sand. Dry clay is different from wet clay. The clay may be so wet that there will be a hydrostatic pressure, or, it may be so dry as to shrink away from the wall without any pressure

against it whatever. Under those conditions how is it possible to deduce a formula that will give accurate results? The only thing that can be done is to use a formula that will give safe results under the worst probable conditions.

The formula I have used for a great many years is very similar to the one mentioned by Mr. McCullough, except that I have used  $15 h^2$  instead of  $16h^2$ . I have always regarded this pressure as being applied horizontally at one-third of the height from the base. With the pressure determined, it is simply a matter of mechanics to work out the stability of the wall.

As regards surcharge, I think all will agree that the old formulæ give greater pressures than are found in practice, but to assume that there is no effect from surcharge is certainly an error, and if Mr. Mohler had followed out his illustration to a logical conclusion, I think he would have arrived at the same result. It would be difficult to explain without a diagram, and I shall not attempt it, but I went into the subject far enough to satisfy myself that if he had properly analyzed the effect of each cylinder on the cylinders below, he would have found that they produced an increased pressure against the wall.

The design and construction of retaining-walls, after all, is a practical question, and it depends more on the method of construction and the drainage of the wall, as Mr. Finley has said, than it does on the theory upon which the design is based. Water will get down back of the wall and freeze. Freezing, it will expand the material and crowd the wall out. The question of drainage is really the most important one in the construction of retaining-walls.

*Mr. Chamberlain:* I think Mr. Armstrong has brought out very clearly a point in regard to all formulæ which may be used for the pressure on the back of a wall. Of course, to use it practically we would obtain the horizontal component of the pressure, whether we considered the pressure horizontal or not, originally, and whatever formula we use we are confronted with the fact that the same material even, under different conditions, may have a slope which may vary anywhere from a very few degrees to almost horizontal. We have all had experience with gumbo soils. If it is desired to have a retaining-wall built in a place of that kind, if that becomes thoroughly water-soaked, undoubtedly it becomes almost a hydrostatic pressure, because the material will run almost like water; while under extremely favorable conditions, when there has been a long dry season it may be cut down almost vertically and will stand. Now there is a factor that comes in, no matter what formula is used. We have to assume a certain angle of repose for all material, and it seems to me that to split hairs on some other factors in our formula when we have that extreme variable, is rather uncalled for. It is enough for a practical engineer to know that he is assuming a pressure on that wall which is sufficient for the most extreme case—the worst case.

*Mr. E. N. Layfield, M. W. S. E.:* I have no desire to join in the onslaught against the mathematics of retaining-walls, but I have never had much confidence in the value of any of these formulæ for the purpose of designing such walls. I think that feeling is probably based on reading, a good many years ago, the book of Sir Benjamin Baker, referred to by Mr. McCullough, in which I think Sir Benjamin discussed a number of these formulæ at some length, and concluded by saying that for ordinary conditions and ordinary materials without surcharge, if the base of the wall was being made four-tenths of the height, that was about the right thing. I am frank to admit that when the question of designing the retaining-walls of the Chicago Terminal Transfer Railroad track-elevation came up, I sent my assistants around town and found out what all the sections were that had been used on other track-elevation walls, and made a record as to how they were standing, etc. We then made a composite design that looked right to us and built several miles of it and it is still standing. I will say, however, that the ground under nearly all of these walls was of such a character that we considered it necessary to put piling underneath so that they had a solid foundation, which was practically equivalent to the rock foundation that has been spoken of. It became necessary, in some cases where it was impracticable to get the pile-driver close enough to buildings to put the piling near the toe of the wall, for us to do considerable figuring as to thickened walls in order to take care of that changed condition. As will be readily seen, that was merely a question of moments and had nothing to do with the calculation of earth-pressure.

*Mr. I. F. Stern, M. W. S. E.:* I think that Mr. Layfield has just touched upon the crux of the matter when he said, "We designed a wall that looked good to us." It is fortunate that the making of the design and the passing upon it are in the hands of men who have had the preliminary experience to appreciate that even though the figures do show something, if the plan does not look good it ordinarily is not. It is like making estimates, in which we have all had considerable experience. We make an estimate and then guess at what we think it ought to be, and if our guess and our estimate do not agree, we make our estimate over again and find where we made an error in our figures.

I do not care to join any mathematical discussion at this time. I have gone into that and in a measure tried to forget it and simply to retain the idea of what is right and what ought to be right. I think Trautwine says in the beginning of his handbook that an apparently simple subject can be hidden by a whole lot of mathematical analysis. He is right. But I do not think many people understand what he meant. What he meant was, in my way of thinking, that we are afraid of a mathematical analysis as a general thing, but that if we look at it in a fearless way, as we ought to look at the

whole study of mathematics, we will find that after all that part of it is the simplest part of the entire problem.

I have listened to the various speakers, beginning with Mr. McCullough and ending with Mr. Layfield, and, after all, we have based everything that we have done upon the old analytical theory of Rankine. Rankine in his figures assumed the slope of earth and said that we had to do that,—we had to get some basis for it. Now, once assuming a certain slope for the earth, assuming that we have a granular mass that will remain in a quiescent condition at this certain slope, the mathematics are very simple, very simple indeed. As Mr. Finley has pointed out, the trouble lies in the fact that we do not always assume the right thing. We have our clay and we have our sand and we have our water-soaked soil, and we do not know at just what slope they will stand up, but assuming a slope, and then adopting Rankine's analytic method, which develops into the conjugate pressure idea which is really the basis of it all, we have even very simple graphical solutions.

I want to pay a tribute to an old professor of mine, one of whose principal virtues was in finding graphic solutions for the statements of Rankine, and these statements were generally correct,—Professor Green, now dead and one time professor at the University of Michigan. If you will refer to his book on the subject you will see that the computations by graphics are as simple as by analytics, and there is very little to the computation. If we get our conditions right, that is all there is to it, and all of the theories that have been given out after all come back to that. The formula of  $15 h^2$  or  $16 h^2$  is based absolutely on a weight of earth of from 100 to 107 lb. to the cubic foot, and a slope of earth of  $1\frac{1}{2}$  to 1. Now, if we approach those things without fear and trembling and say we have to make some assumption so as to guide us in our figures, we then draw up something that looks right and it is probably quite right.

I discussed with Mr. Armstrong the diagrams of the solutions made by Mr. Mohler, and it seemed to both of us that while we agreed with his demonstration that for the particular solution involved there was no increase due to surcharge, that simply meant that the surcharge did not affect the top of the wall, but down below the surface of the ground, below the top of the wall, the surcharge was noteworthy, and if Mr. Mohler will carry out his figures and go down below the surface I think he will agree with us.

*Mr. E. P. Goodrich*, M. AM. SOC. C. E. (by letter): In his experience, the writer has repeatedly had his attention drawn forcibly to the fact that almost nothing is at present known about earth pressures and the various problems in which they are factors. But few tests have been made or data secured as to the compressibility, viscosity, and elasticity of soils, although an intimate knowledge of these three properties is absolutely essential to a full treatment of earth-pressure problems. One illustration of the lack of knowledge

on the part of engineers is given by the author in his citation of the celebrated middle-third proposition and of its frequent erroneous application. It should be considered by all designers that every structure like a building-foundation, bridge-pier, or arch-abutment will shift and settle to some extent (often very slightly) when loads are brought to act upon it, but account is invariably taken of this fact in every well considered design. Most soils exhibit a very appreciable amount of elasticity, which, in connection with the compression produced at considerable depths or because of superimposed loads, combined to some extent (depending upon the soil) with a sort of viscosity, is what produces the earth pressures concerning which so many theories have been devised from time to time.

Concerning the old theory of Vauban as interpreted by Coulomb, Rebhann, Prelimi, etc., little need be said beyond the criticisms of the author, except to note the simplicity of the application of the graphical method, which can be adopted even to the case which has been called by the author excessive surcharge, simply by changing the value of  $\gamma$ , very much in the way which is explained by S. W. Hoag, Jr., of the New York Dock Department, in his paper on *The Department of Docks and Ferries and the New York Docks*, contained in the Proceedings of *The Municipal Engineers of the City of New York*.

Concerning Rankine's theory, it should be observed that he repeatedly states its applicability only to conditions of indefinite extent of top surface (*Civil Engineering*, 1894 ed. pp. 321, 324, etc.); and while the analytical method may be theoretically applicable to every angle of slope of back of wall, still Rankine makes use only of the pressures against a vertical plane, modifying the location of the centre of gravity of the masonry or the weight on the base so as to care for the mass of earth or masonry between the vertical and the back of the wall. With strict adherence to these points, the author's criticisms of the Rankine theory are not justified.

Another point in which the author's theory is equally as defective as the others he mentions, is that he makes use in his formulæ of the symbol  $\phi$  as applied to the "angle of repose or natural slope" (as do all the others), although later the author discusses the "angle of resistance to flow," which is also mentioned by Rankine as the "angle of repose . . . . between the portions into which it (a mass of earth) is divided by any plane," each of which terms really correspond with what the writer has called the "angle of internal friction." (See *Earth Pressures and Related Phenomena*, Trans. Am. Soc. C. E., Vol. LIII, 1904, p. 292). Just so long as inventors of earth-pressure theories measure the induced internal stresses in terms of the angle of *surface slope* (however modified), will their theories fail to accord with facts, and the author is believed open to this important criticism along with the other authors he criticises.

The author has done much valuable work in analyzing the two

great earth-pressure theories and in collating the results of his analysis, if for no other reason than to show how the several theories are not to be applied. But when it comes to the analysis, through which he claims to deduce the conclusion that no more pressure is produced against a wall with vertical back, whether there is a surcharge fill or whether the fill runs "off level or even *sloped down away from the back of the wall*" (the italics are those of the writer), the writer believes the author to be seriously in error. This conclusion is reached by the writer through study of such experiments as those of Darwin (*Minutes of Proceedings, Inst. C. E., Vol. LXXI, p. 350*), Steel (*Engineering News, Oct. 19, 1899, Vol. XLII, p. 261*), etc.; as well as by the following analysis of conditions assumed much like those in Fig. 8 of the original paper. In this survey will be ignored for the moment the author's statement of questionable truth that "the net resultant of the squeeze will be at right angles to the force of gravity . . . . whether the wall carries a surcharge or not." (The above quotation is not seriatim from the text of the paper, but is believed, nevertheless, to state the conclusion of the author.)

Assume a pile of cylinders as shown in cross-section diagram in Fig. 12. The action of gravity on each is represented by the vertical arrow through the center of each circle, while the small arrows show the points and directions of the pressures exerted by each on the cylinders beneath. Upon the assumption that the angle of slope of the pile is  $60^\circ$  from the horizontal, it is evident that each little pressure will be transmitted directly through each lower circle without reduction, so that if the final resistance is for the moment considered as acting along  $60^\circ$  lines, as shown in Fig. 13, it is seen that the left-hand arrow in the latter figure must equal three of the small downward arrows in Fig. 12, corresponding to the three left-hand cylinders in the pile; while the next upward arrow in the same direction to the right must equal two, and the next only one downward diagonal pressure. Similarly, the pressures exerted by the left cylinders in the pile shown in Fig. 14 are as shown therein to be such that the lateral equilibrating pressures would increase downward according to the series 1, 3, 5, etc., to infinity, provided the top surface is of that extent, but increase only to a constant value in the case of a mass of definite width such as the contents of a bin. This latter is seen to check with remarkable exactitude with numerous experiments, and with the best bin theories. According to Fig. 15, however, when the top slope is at an angle of  $60^\circ$ , it is seen that the lateral resisting-force on the down-hill side of the slope is equal for all depths when the mass is of limited extent, and it is evident that the uppermost arrow is much larger than in the case of a horizontal top. On the up-hill side, the arrows are seen to increase in length with increase of depth to the same ultimate value as for the other side, but an important difference is found in the fact that the rate of increase is only half that of the condition with horizontal



Fig. 12



Fig. 13.

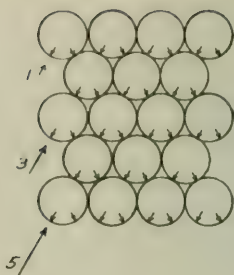


Fig. 14.

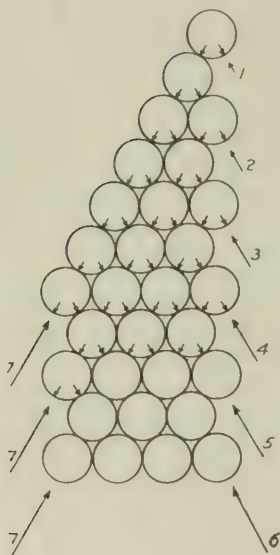


Fig. 15

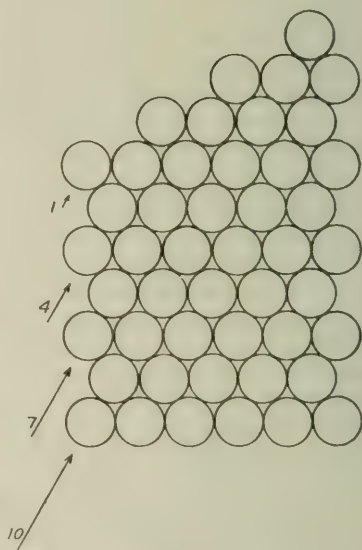


Fig. 16

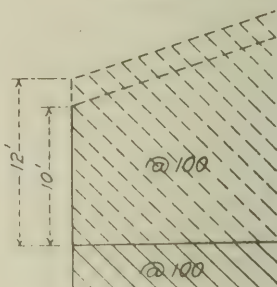
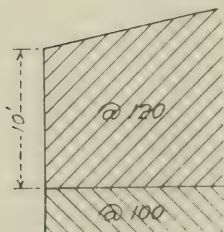


Fig. 17

Illustrations to discussion by E. P. Goodrich.

top, viz., 1, 2, 3, 4, 5, etc., against 1, 3, 5, etc. According to the diagram, if the mass is infinite in extent, the necessary lateral resisting-pressure would theoretically also have to be infinite, and equal for all depths. This is perfectly consistent with the conditions of the problem as assumed, because practically all actual natural conditions have been set aside in making the assumptions, but furthermore it is closely in accord with facts as encountered in cases of large slides where it is practically impossible to construct walls which will resist the earth mass, because in this case the lateral component of the whole weight of the gigantic sliding-mass must be resisted. (See "*A Phenomenal Land Slide*" by D. D. Clarke, *Trans. Am. Soc. C. E. Vol. LIII 1904, p. 322*.) The writer has experienced several cases of such enormous pressures on the sides of slopes, one example being the crushing of heavy braces placed across a sewer trench only about 3 ft. wide and 6 ft. deep, the ditch having been cut along a side hill composed of damp clay. Intermediate conditions between those of Fig. 14 and the down-hill side of Fig. 15 will give a lateral pressure, increasing with depth and at a rate greater than in the case of a horizontal top. Such a condition may be illustrated as in Fig. 16, where there is seen to be a real increase with depth, but this is seen to be greater than in the case of a horizontal top.

Obviously, in order to secure actual horizontal or other pressures in the diagrams above, it is only necessary to resolve the upwardly-directed arrows horizontally and vertically, for example, the horizontal component being the one desired, while the vertical component is to be assumed as resisted by friction against the back of the wall or other proper resisting-factor.

Taking up the author's analysis of his Fig. 8, it would seem to the writer that the value of  $P$ , when deduced in accordance with the author's method, could be only of such size as just to equilibrate the single cylinder on which it is applied with this assumption. The value of  $P$  would be constant for all depths, however great or small, which is contrary to fact; and for cylinders of infinitesimal size, like grains of sand, the lateral pressure would itself be infinitesimal, which is again contrary to fact.

Moreover, the writer has found by experiment that under certain circumstances in nature, almost the exact condition actually exists which the author derides as impossible when he says, "we would have the anomaly of the toe of a natural slope of an embankment carrying a load greater than the weight of the material in the vertical projection above." The writer found that with certain kinds of compressible soils, the *edges* (and even more pronouncedly the corners) of a column footing, for example, had to resist several times the earth pressure developed under the center,—probably due to the very arch action which the author derides.

It would therefore seem that the author's primary assumptions are wrong, except in so far as he has made an endeavor to get at

the conditions of so-called *flow*, which, however, should be approached from a different standpoint, in the opinion of the writer.

It seems to the writer that the author is entirely wrong in comparing a surcharge greater than the surface angle of repose with a deep lying soft layer overlaid by strata of heavy materials. A much fairer comparison seems to the writer to be between the actual stratum in question and one in a fill entirely composed of the soft material, but of a new depth and perhaps also a surface slope such that the vertical pressure produced at the stratum in question will be that of a properly selected one in the new assumption. In Fig. 17, for example, suppose a stratum of soft material 10 ft. below the surface, overlaid by material 12/10 as heavy as the soft layer. Obviously, the same conditions, as far as concerns the special layer in the figure, are secured by assuming a bank 12/10 as high and composed of the soft material.

Again, the author's illustration of the bank of clay which will stand with a vertical face for several feet, but will flow at great depths, does not seem at all comparable with a surcharge exceeding the angle of repose unless it be considered as described in the last paragraph above. It seems to the writer that the true situation is found in the fact that the *angle of internal friction* changes with depth, and this is a condition of which none of the theories—even the author's—take account unless it be by the device explained above.

The writer's experiments on full-size retaining-walls over 30 ft. high, as well as on models, have led him to the opinion that the resultant of earth pressures is usually located *above*, instead of below a point two-thirds down from the top as the author states. Nor does the writer understand how the accident, described by the author at the end of his paper, proves anything at all as to the location of the resultant of the pressures which existed. In that case there existed downward, lateral, and upward pressures, and it was the resistance offered against the last named pressure immediately under the steam shovel which failed.

Finally, after a considerable study the writer cannot work out any consistent reason for the formulæ used by the author, unless the symbol  $\phi$ , as used by him, refers to an angle entirely different from that usually understood. It seems quite possible to devise a formula starting from the idea of hydrostatic pressure, but the writer's experiments with clay show that the angle of internal friction, which is the nearest equivalent which he knows to the author's "angle of flow," alters widely with the depth, so that the symbol  $\phi$  must also vary if the author's theory is to be of any value. Again, it seems as if there should be some means of making a formula which could be applied to walls with back slopes both positive and negative, instead of following the necessity of using two quite dissimilar formulæ as the author has done. In the very fact that two

dissimilar formulæ are necessary, is to be found a marked "break down" of the author's theory, in the opinion of the writer.

As stated above, the author has done much service in disclosing the weak points of the existing earth-pressure theories and for that he deserves the thanks of the profession.

*Mr. John H. Griffith*, ASSOC. M. AM. SOC. C. E. (by letter): The writer has read with interest the paper presented by Mr. Mohler, without, however, devoting to it that more rigorous analysis which its merit would of necessity demand.

He has never been quite clear as to the real significance of the angle of repose in this and similar theories. For example, the author cites the piling of barrels in the case where "they will stand with a natural slope of  $60^\circ$ , and are held in this position by friction alone," etc. It would appear to the writer that after all,—despite the im-

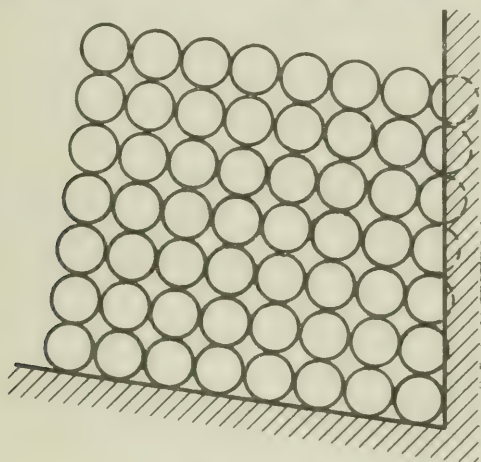


FIG. 18

portance that this function is usually given in the theory,—the slope is quite arbitrary rather than natural, and that the barrels owe their stability, not necessarily to friction in the case cited by the author,—although this of course is an important contributing factor,—but quite as much to their own inherent configuration and inertia. In fact, in the array given by the author, purely frictionless cylinders or balls would be very stable of position, provided, of course, as in the author's implicit assumption, that the base of the pyramidal array is restrained against displacement.

On the other hand, taking the array of Fig. 18 for example, if one is to presuppose the hypothesis of friction, then quite a fair amount of stability may be assured for almost any angle of repose up to  $90^\circ$ . As an instance, an array of kegs of white lead may be

conceived as comparatively safe at an angle of, say,  $80^\circ$  or  $85^\circ$ , especially if an unreasonable amount of jar in the warehouse were eliminated,—at least as far as the analysis is concerned. Much more would this be the case if, instead of cylinders of circular cross-section, prisms of a finite number of sides are assumed, such assumption approximating the actual earth quite as easily as circular cylinders.

It has been the writer's experience that almost any theory may be fitted to the facts by a proper recourse to the already extensive statistics of angle of repose, these several angles of various investigators being either widely different in value, or, if agreeing among themselves, having been deduced under certain particularized conditions which cannot be fulfilled in practice.

The fundamental weakness of those methods which are made to depend upon the angle of repose is that they implicitly introduce the time-element into a static analysis, without making adequate analytical provision for the evaluation of this variable in the solution. The writer would ask whether the time has not arrived when this matter should be considered from a larger circle of vision.

To be sure Greenhill\* has met some of the criticisms of the indetermination of solutions by such methods in proposing "an exact theory of earth pressure," which differs somewhat from the Rankine case in assuming the cylinders or balls lifted out of the "cusps" and being arranged as is illustrated in *a* and *b* of Fig. 19. Assuming the same slope as given by the author, of  $60^\circ$  for the equilibrium of the mass DEIN having the weight *W*, the thrust *Q* on the wall here becomes

$$Q=W \cot 60^\circ.$$

Upon taking *w* for the specific weight of the earth material, he gives

$$W = \frac{1}{2} wl (h^2 - b^2) \cot 60^\circ = wl \left( \frac{1}{2} a^2 + ab \right) \cot 60^\circ$$

and

$$Q = wl \left( \frac{a^2}{2} + ab \right) \cot^2 60^\circ = \frac{wl}{3} \left( \frac{a^2}{2} + ab \right)$$

where *a*=the height of wall

*b*=amount of surcharge

*h*=total height

*l*=length of wall

\*Greenhill, "Hydrostatics," p. 49.

This is equivalent to the hydrostatic thrust of a liquid having the specific weight  $\frac{W}{3}$  acting on the wall.

Similar attempts have been made by others from time to time and will doubtless continue to be made for years to come, as long as engineers persist in toying with elementary abstractions of the problem. But at best any of these methods are destined to be unsatisfactory scientifically, because dependent upon premises which are ideal rather than in accord with actual conditions ;—for example, such as are involved in the predication of rigid particles, zero cohesion, a rigid wall rotating through an infinitesimal arc about the base, a constant coefficient of friction, the assumed equality of the internal angle of friction with the angle of repose, and the like. They omit altogether the very important idea of internal strain

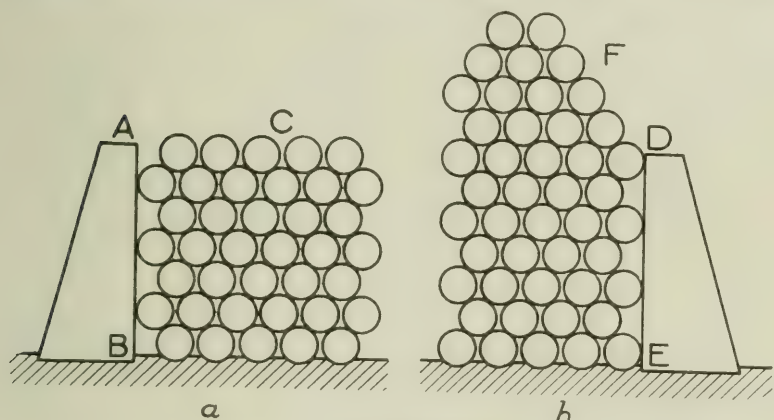


FIG. 19

which is necessarily involved in all mechanical analysis. If such limiting assumptions are to be made, they should be at the end rather than at the beginning of the analysis. The objection to reversing this order of procedure is that nearly all investigators of a later period are constrained to the groove of thought of the earlier scientist, and little progress is made in the larger and more general theory.

Consider such a case as is illustrated by C, Fig. 20. Since the engineer is prone to highly idealize his problem to suit the exigencies of his case, let the "earth" be considered as made up of frictionless cubes which are confined by rigid walls. What is the lateral pressure of the earth, assumed to be elastic, upon the walls when under its own head together with that of some initial head due to a frictionless piston as shown? Clearly such a problem is solvable

mechanically, if the strain constituents of the medium are known. It has been solved. Now suppose, as nearer the actual case, the idea of elastic spheres, say either smooth or possessing a certain degree of roughness. Theoretically such a case is solvable; practically it is not, because the engineer cannot make any particular assumptions such as cubes, spheres, or of jagged angular particles. He must therefore either resort to the idea of a mass continuum, as was tacitly done by Rankine, or, if heterogeneous particles subject to finite slippings under pressure are conceived, a certain average configuration of these must be investigated. In either case the ensuing stress and strain relations can only be determined by a testing-machine process, just as Poisson's ratio, and other moduli are measured

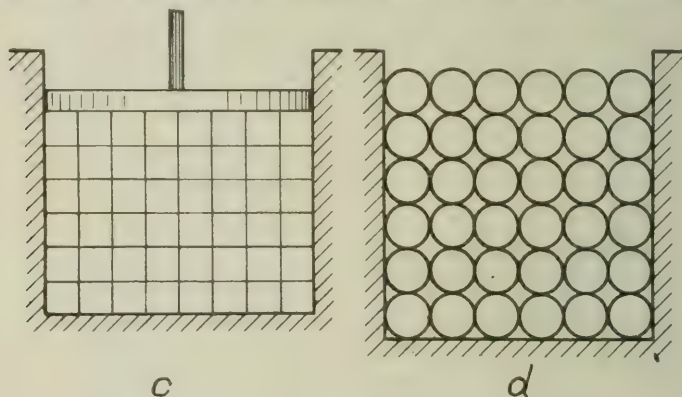


FIG. 20

in any other structural material. Some of the most careful work along this line has been done by Goodrich (*Trans. Am. Soc. C. E.* 1901, LIII, p. 292) in his cylinder and plunger experiments. Goodrich, however, is rather committed to the Rankine point of view, and has proceeded upon the hypothesis of incompressible particles. However, just how far the hypothesis of particles under maximum displacement and maximum friction approximates to the truth is difficult to say.

Since the days of Vauban, Rankine, and Rebhann, a great deal has been written upon this subject. The contributions of real value to the writer's mind are the works of Boussinesq<sup>a</sup> and Kötter<sup>b</sup>, and of those who write from their point of view, such as Flamant<sup>c</sup>, Pearson<sup>d</sup>, Mueller-Breslau<sup>e</sup>, etc. In fact it would appear that

<sup>a</sup> Essai théorique l'équilibre délasticité des Massifs pulvérulents et sur la pousée des terres sans cohésion. (Bruxelles, 1876.)

<sup>b</sup> Die Bestimmung des Drucks an gekrümmten Gleitflächen, eine Aufgabe aus der Lehre vom Erddruck (Berlin, 1903).

<sup>c</sup> Résistance des Matériaux (Paris, 1886).

<sup>d</sup> History of Elasticity, Vol. II, Part II, Art. "Boussinesq (Cambridge, 1893).

<sup>e</sup> Erddruck auf Stützmauern (Stuttgart, 1906).

Boussinesq has largely placed the whole theory upon a strictly rational basis, much as did his illustrious master, de St. Venant, for the beam analysis. It remains for later investigators to work out the details in theory and by experiment.

The modern theory of earth pressure may properly be said to date from Rankine (1856), who, in applying the equations of equilibrium to an indefinite extent of earth, has suggested the outlines to be followed by those who come after him. Later writers, however, instead of following in the course thus marked out by this constructive scholar, usually wander into devious paths. At the very outset they are thrown upon the horns (the pressure on the face and the angle of repose) of that *bête noir* of the empiricists, and from such an encounter they of course do not readily emerge.

Boussinesq in his *Essai théorique* . . . third chapter, *et seq.*, has happily taken up the problem just where it was left by Rankine. Although his work was published as early as 1876, and has been supplemented by articles in the *Annales des Ponts et Chaussées* and *Compte Rendu* from time to time, it has been little studied by engineers. This is the more inexcusable in view of the admirable critique by Pearson in his *History of Elasticity*. The results of such experimenters as Darwin, Wilson, etc., made with a full consciousness of the importance of the Boussinesq theories are usually dismissed with a passing remark as impracticable by American authorities. But these efforts are in the right direction, although their results are qualitative rather than quantitative, and the theories which they seek to confirm will ultimately displace the elementary notions. In the various fields of structural engineering, a science becomes rational just about in the proportion that the engineer resorts to the elastic methods in his investigation of stress and strain.

Mr. Mohler has made a careful and painstaking effort in this rather uncertain field of research. In thanking him for his contribution, the writer hopes he may be won over to the elastic point of view, indefinitely as it may be formulated at this time.

#### CLOSURE.

*Mr. Mohler:* It was my purpose to treat of earth-pressure, rather than wall designs and failure on which a large part of the discussion has centered. While I would be very glad to discuss those subjects quite fully, I will have to confine myself to a few remarks and reserve the subject of wall design and failure for possibly a future paper.

#### EARTH-PRESSURE THEORIES.

I can only say, in answer to Mr. McCullough, that as Rankine offered his theory with doubt and misgiving, I do not believe we should be called upon to offer any apology for pointing out some

of the glowing inconsistencies. I will call attention again specifically to the typical case, back of wall vertical, angle of repose ( $1\frac{1}{2}$  to 1)  $33^{\circ} 42'$ . For level fill back of wall Rankine gives the pressure as 14.3 lb. and under the same conditions with surcharge added he gives the pressure as 41.6 lb. per sq. ft., or nearly three times as great. I for one have not been convinced that is anywhere near the truth.

Personally I find Rebhann's graphics, as presented by Professor Prelini, much simpler and of wider application, than Weyrauch's graphics as given in Professor Howe's *Retaining Walls for Earth*. As stated in the paper, to get results from the formula is certainly a discouraging task even after one has once learned how.

#### WALL FAILURES—POOR DESIGNS.

The reason assigned for the failure of the wall shown in Fig. 1 may be satisfying to our habit of blaming the foundation for nearly all wall failures, rather than improper design. Fig. 21 is redrawn from the original plan for the wall shown in Fig. 1. The drawing shows the total height of wall to be 23 ft. The foundation bed is  $6\frac{1}{2}$  ft. below the base of rail. It is my recollection, and the photograph shows, that the side ditch spoken of is very shallow, the surface being almost even with the tops of the ties. With that depth of foundation it is hardly to be supposed that surface water was responsible for any such settlement and tipping as took place.

Let us look for the cause in another direction. The center of gravity of the loading cuts the base 9 in. in front of the center of base. The load factors assumed are: Masonry, 150 lb. per cu. ft.; backing, 100 lb. per cu. ft., and bridge load, 6,000 lb. per lineal ft.; making a total of 38,650 lb. per lineal ft. of wall. By using Mr. McCullough's factor for earth pressure we get  $16h^2=16\times 23^2=8464$  lb. horizontal earth thrust. That throws the resultant forward to cut the base at 7.93 ft. from the heel, or 2.18 ft. in front of the center, and 0.26 ft. outside the middle-third. The average foundation reaction is  $p=3361$  lb. per sq. ft., not a heavy average load. The toe reaction is  $p=7193$  lb. The heel reaction is negative 471 lb.= $p_2$ . In other words the toe reaction is so greatly in excess of that at the heel, the wall can not do other than settle at that point, and tip forward, on a compressible soil. We even have tension in the joints at the back of the wall which we are theoretically to guard against.

As a further proof that *bad design* and not *bad foundation* is responsible for the partial failure of the wall shown, I would like to call attention to the partial failure of wall shown in Fig. 22. This wall is one block away from the one shown in Fig. 1. Instead of a ditch in front there is 14 ft. of sidewalk with a curb wall and paved roadway beyond. The wall is 13 ft. high at the end shown, and 11 ft. high under the center of the bridge, above the sidewalk. As is clearly shown, the failure in this case is more pronounced than in the case of Fig. 1. It will be noted still further that Fig. 21 shows

a conventional design of wall, and that the ratio of base to height is five-tenths. Sir Benjamin Baker is quoted as saying that "for ordinary conditions and ordinary materials without surcharge, if the base of the wall was being made four-tenths of the height that was about the right thing." I believe the "conditions" about these walls are only "ordinary." With due respect to Sir Benjamin Baker's opinion. I am constrained to say that four-tenths may or may not be

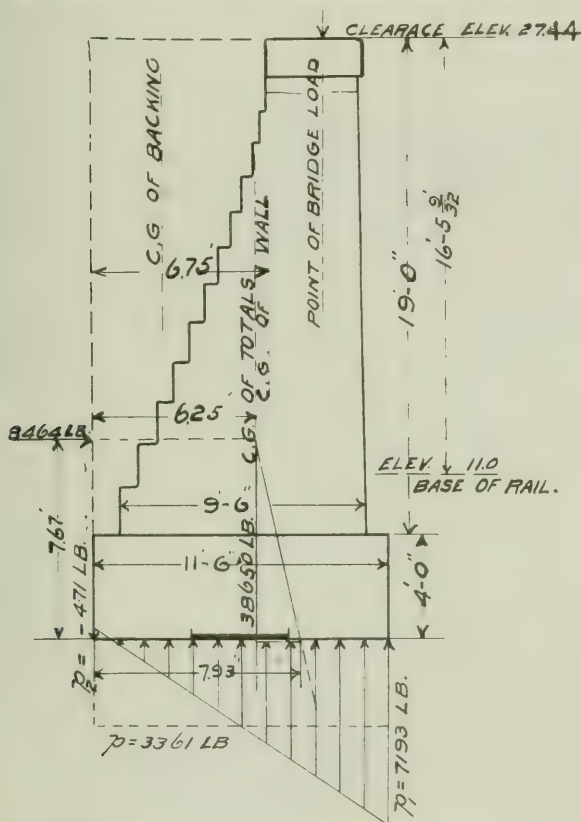


Fig. 21.

Sections of Fig. 1, showing foundation sections.

"about the right thing." I suppose there are very few walls in Chicago with a thickness of less than four-tenths the height. Tipping and cracking seems to be almost universal. You blame the foundation? I do not in one case out of ten, where we have such partial failures as shown. The answer is still in two words not *bad foundations*, but *poor design*. This may seem like a strong statement. It is one, however, which I believe I can fully substantiate. We have fallen too

much into the habit of taking refuge in such statements as in another quotation to-night from Sir Benjamin Baker "that for an engineer to claim he had no retaining walls fail simply proves his inexperience, and was no argument to show he possessed superior ability."



Fig. 22.—Failure of a low abutment with wide sidewalk in front.

A wall failure such as we have been considering can hardly mean other than that the designer either *did not recognize* or *could not discover* and properly provide for the important elements entering into the problem. The persistency with which the middle-third

theory has clung, would seem to indicate that it is largely a failure to *recognize* some of the facts.

SURCHARGE.

Taking up the questions dealt with in the paper on earth pressure, raised particularly by Mr. Chamberlain, about surcharge not producing any greater pressure than for level fill back of wall, the same questions being dealt with at some length by Mr. Goodrich in his communication, I may answer the questions raised, in part, by asking some others. In Fig. 23 let A B C D be a part of an embankment which has fully settled and is in stable equilibrium. Pass a vertical plane through C E. As the particles of the bank are in equilibrium, then the particles on each side of the plane C E must be in equilibrium, otherwise movement would take place. Again the action and reaction in this case must be equal, or movement must result. If the above hypothesis is correct, must we not conclude that

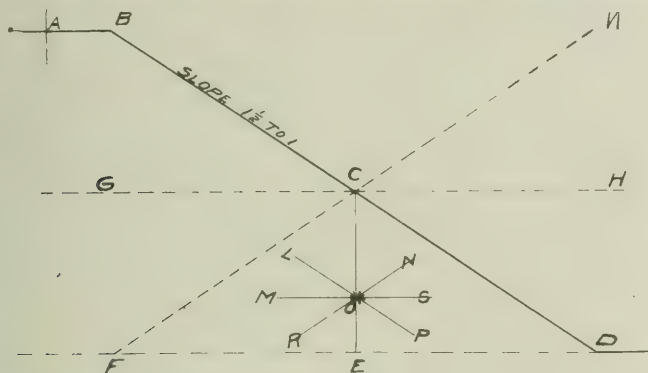


Fig. 23

### Effect of surcharge on the amount and direction of earth pressure.

the pressure against the right side of the plane is equal to that on the left? The conditions, however, giving these reactions are, on the left of the plane a surcharged bank, while on the right the bank slopes down away from the plane or is a negative surcharge.

Then again, under the above conditions of equilibrium is it to be supposed that there would be any material change in balance of the forces acting on the plane C E if the following changes were made in the slopes terminating at the plane C E?

- 1st, Remove the wedge B C G. C G level
- 2nd, Build up the wedge H C D so that C H is level
- 3rd, Remove the wedge G C F so that F C has a slope of  $1\frac{1}{2}$
- to 1.
- 4th, Build up the wedge K C H. C K with a slope of  $1\frac{1}{2}$  to 1.

Have we any reason to believe that any of these changes will disturb or change the equilibrium of the forces acting on the plane

C E? In other words, the triangle C D E is an effective retaining-wall to hold the earth particles or pressure to the left, whether coming from the slope B C, G C, or F C.

Let us consider for a moment where the old theories are leading us to when we come to consider the resultants. Rankine says the direction of the resultant is parallel to the surface-slope, back of the wall. Then we get

For slope B C	the resultant direction	L O
" " G C	" " "	M O
" " F C	" " "	R O
" " D C	" " "	P O

Rebhann says that the resultant makes an angle with the normal to the back of wall downward equal to the angle of repose.

Then for slopes B C, G C and F C we get L O as the direction of the resultant. On the other side of the imaginary plane the direction of the resultant changes to N O.

It seems strange that these resultants have to be shifted around in that way when we change from one side of an imaginary plane to another. Is it reasonable to believe that the forces acting on an imaginary plane, as C E, passed through any part of an embankment are any different than if they were acting on an actual retaining-wall? We are hardly justified in any other conclusion than that the resultants act in a horizontal direction and are equal and opposite on both sides of the plane C E, regardless of the direction or extent of the surface slope. I would again call attention to the statement made at the bottom of page 783.

To answer specifically some of Mr. Chamberlain's points. The use of the cylinder sketch in Fig. 8 was to show that the distribution of pressure was downward rather than along the "natural" or "surface slope." Of course they must be carefully piled and have the required amount of friction between the points of contact. I will have to take issue with him on the statement that a surcharge of earth will not stand at an angle of  $60^\circ$ . There are plenty of cases where earth stands at a vertical. In deep railroad cuts near Sioux City, Iowa, I have seen the slopes made apparently as steep as  $\frac{1}{2}$  to 1 and they were standing perfectly. The use of the illustration with the cylinders was not intended to prove or even imply that earth banks would stand at  $60^\circ$ .

*Cylinder Experiments:* I can perhaps do no better than to give at this point a few photographs and the results of some experiments made with cylinders. The weight of each cylinder was  $1\frac{1}{2}$  lb.; diameter,  $3\frac{3}{8}$  in.; surface, tin with angle of friction  $23^\circ 25'$ ; slope at which sliding would take place, 2.33 to 1. Fig. 24 shows the number of bare tin cylinders that would be held in position against the slope by the weight and friction of the upright stop on the left. The last cylinder to the left resting on the table was blocked so that no pressure was transmitted from any of the cylinders except the

three lying on the slope. By careful placing the three would usually be held in position, but often slid down.

The fixed vertical at the right and the sliding stop-block on the left are most clearly shown in Fig. 26. In all cases the last cylinder to the left resting on the table was blocked. That cylinder with the row inclining upward to the right, formed the base from which pressure to be transmitted to the stop-block on the left originated.

Fig. 25 shows the number of cylinders held in position with a "negative" surcharge. The conditions for this experiment were the same as for the previous one except the piling of the cylinders and that the stop-block was 0.69 lb. heavier. The stop would hardly



Fig. 24.—Cylinders retained in position, tin on tin.

hold the three cylinders in this position. The photograph was taken after they had slipped down. Note the open space between the two cylinders in the second tier. The stop-block could only move back about  $\frac{3}{4}$  in.

A number of tests were made with the bare tin of the cylinders in contact. Then pieces of sand-paper were glued on to the cylinders so as to cover the bearing of the two cylinders upon which the one above rested, giving a contact of sand-paper on tin. The angle of friction, or the angle at which sliding took place with sand-paper and tin, was  $33^{\circ} 42'$ , or at a slope of  $1\frac{1}{2}$  to 1.

Fig. 26 shows the results obtained. Ten cylinders were held in position by the stop-block without slipping. I do not know how many more it would have held in position as not enough cylinders were available to build any higher. The weight of the stop-block was 1.68 lb. and the angle of friction between the surface of contact  $36^{\circ} 45'$ , the same as for Fig. 24. In the case of Figs. 25 and 27, an extension was tacked on, bringing the weight of the stop up to 2.37 lb.

Fig. 27 shows sixteen cylinders with the sand-paper held in position as follows: The first sloping row is composed of seven cylinders; the second, five; the third, three; and the fourth, one.



Fig. 25.—Cylinders retained with tin on tin.

In the case of Figs. 24 and 26, the amount of resistance to sliding offered by the stop-block was  $\tan$  angle of friction by the weight  $= \tan 36^{\circ} 45' \times \text{weight} = .75 \times 1.69 = 1.27$  lb. For Figs. 25 and 27 it was  $.75 \times 2.37 = 1.77$  lb. The stop-block was just as stable under the loading shown in Fig. 27 as it was in that of Fig. 25. By increasing the angle of friction of the points of contact by  $10\frac{1}{4}^{\circ}$ , the number of cylinders retained by the same stop-block was increased from 3 to 16, the total weight being 4.5 and 24 lb. respectively. In other words, by increasing the angle of friction between the cylinders 44%, the self-sustaining power is increased at least 433%. The difference of  $10\frac{1}{4}^{\circ}$  in the angle of friction, however, covers the critical point in the case under consideration.

Some interesting computations can be made from the experi-

ments to show where the balance should occur in such a case as in Fig. 27 between the lateral pressure produced and the sliding of the stop-block, but it is needless to burden the discussion with them.

I think it should be conceded that, in making the statement I did in discussing the piling of cylinders shown in Fig 8, it was with full justification and not a visionary guess. I can only repeat that it was only to illustrate and demonstrate a certain principle within



Fig. 26.—Cylinders retained in position, tin on sandpaper.

defined limits. You can unquestionably get many different results by the various possible arrangements.

*Reaction Along the Sloping Rows of Cylinders:* I believe the experiments shown in Figs. 24-27 show beyond question that the assumptions made by Mr. Goodrich in his discussion are not correct, except where the cylinders have little or no friction between points of contact. Even so I must maintain that the number of cylinders to the right or left of any particular point does not give the relation

and direction of pressure that he has assumed, and does not determine the amount of pressure against a plane.

Let us consider Mr. Goodrich's sketch, Fig. 15. To get any such reactions as shown there, the cylinder would have to be devoid of friction or cohesion. The way he has shown the forces acting, the total reaction on the right would be  $1+2+3+4+5+6=21$ , and on the left  $7+7+7=21$ . At the point where the surcharge starts, the reaction is represented by 7 on the left. The reaction of the cylinder to the right in the same horizontal row is represented by 4. In other words, the reaction at the toe of the surcharge is 7 while that vertically under the high portion of the pile is only 4. But if we take the totals, then we get for the right-hand reaction  $1+2+3+$



Fig. 27.—Cylinders retained with tin on sandpaper.

$4=10$ . The left-hand  $=7$ . It is not very clear what conclusions we are to draw. I believe we can safely challenge anyone to prove that the pressure at the foot of a slope of indefinite extent becomes infinity when the entire mass is of the same character as that producing the surface slope.

The cases of slides cited by Mr. Goodrich are only akin to that shown in Fig. 11 of the paper. In that case a putty-like clay was overlaid with sand and gravel. The sand and gravel would stand at a slope of  $1\frac{1}{2}$  to 1, and if the entire mass had been of the same material the slip would never have occurred. As it was, as soon as the clay was uncovered it flowed out through the opening, the high portion of the bank sheared off and sank into the bed of clay, and a new

equilibrium was established at a much flatter slope. Such conditions as that, and slippery hill-sides, are what produce the unusual conditions, and get us into trouble. Rankine and Rebhann have given us no help when we have a surcharge greater than the angle of repose. I have attempted to deal with the conditions to some extent, see Figs. 5 and 6. I do not claim to have said the last word on the subject by any means. It is one of the most important conditions to be met, and I do not believe I have made allowance enough for conditions of that kind. If conditions were as pictured by Mr. Goodrich in Fig. 15, the slope of the bank would never stop sliding. If a shovelful of earth were taken away at the bottom of the slope, a slice of the bank would immediately move down to replace it. As a matter of fact, we know that we can just as readily dig away a portion of a settled bank at the foot of the slope as we can at the top, without its sliding.

Referring again to Fig. 15. Suppose we remove the lower left-hand cylinder and with it the one diagonally above, and the other two at the lower end of the other diagonal rows. The values indicated by the diagonal arrows would be represented by five instead of seven. There would be four of them instead of three. That gives  $4 \times 5 = 20$  as against  $3 \times 7 = 21$ . By raising the height of the surface retaining the cylinders we get a decreased reaction. I may have the wrong conception of his proposed demonstration, but these seem to be some of the developments.

I would like to call attention to some features that may be developed from Fig. 28. Consider N O T S a bin filled with cylinders; surcharge N S. If they are without friction they would remain in equilibrium, as shown, and develop practically hydrostatic pressure, the amount of pressure on N O being equal to that on S T. If there was just sufficient friction between the points of contact to be on the point of sliding, then the reaction of 6A against N O would be twice that of 14A against S T. The reaction of 14A against S T is the weight W tending to rotate it about the point of contact the same as explained in Fig. 8. If all of the cylinders were just at the point of slipping on their points of contact, then the reaction would be carried through the series from 14A to 6A where it would be transmitted to the side of the bin N O. In addition to that, we would have the reaction of 6A, which is equal in amount. The series 4B-12B and 2C-10C would react in the same way. For the balance 1D-8D, 1E-6E, 1F-4F, etc., the reaction would tend to be carried to and absorbed by the floor of the bin. If the friction between the points of contact amounts to an angle greater than  $30^\circ$ , then the reactions originating in 14A, 12B, etc., would tend to be absorbed in the body of the mass and carried to the floor of the bin before reaching the side N O.

Does it seem reasonable to believe, with a bin piled full of cylinders having friction at points of contact greater than  $30^\circ$ , as in

Fig. 28, that the pressure against the side N O is anywhere near what it is on S T? Mr. Goodrich's method would give  $9 + 9 + 9 = 27$  against N O and  $1 + 2 + 3 + 4 + 5 + 6 + 7 = 28$  against

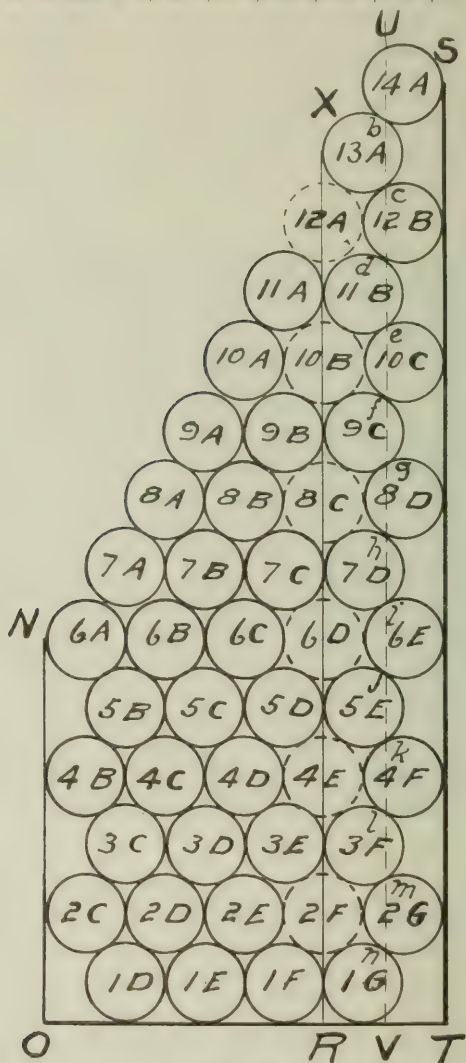


Fig. 28

Effect of surcharge in the piling of cylinders under different assumptions.

S T. For the surcharge portion, the force at 6A would be 9. That coming to 6E along the diagonal row would be five. Total on left, 9. Total on right,  $14A - 6E = 1 + 2 + 3 + 4 + 5 = 15$ .

*Extent of Material Back of Retaining Surface.*—I have made the statement that the extent of the material back of the supporting surface has no influence on the amount of the pressure. Consider the right-hand portion of Fig. 28. Pass the plane XR just at the left edge of 1G, 3F, 5E, etc. Without friction the resulting pressure on XR and S T would be developed by two different factors—first, by the tendency of the cylinders to rotate about the points of contact b, c, etc., and, second, by the wedging or sliding tendency on the points of contact. The rotative reaction would be constant for all cylinders, no matter what their position. The wedging or sliding reaction would increase with the depth. Suppose the dotted cylinders 2F, 4E, 6D, 8C, 10B, and 12A were removed. Counting 2G and the others it supports, gives the weight of thirteen cylinders to produce the wedge or sliding thrust at the point of contact n, cylinder 2G, instead of two as called for by Mr. Goodrich's theory. If the angle of friction between the points of contact is  $30^\circ$ , or over, then we would only have the reaction against S T or XR resulting from the tendency to rotate about the points of contact n, m, l, etc. The rotative force of 2G would be no greater than that of 14A; center of pressure at half the height. This is the factor that perhaps accounts in part for some writers and experimenters claiming that the center of pressure is higher than one-third the height from the bottom.

It is quite true that actual conditions in an earth bank are very materially modified from the cases considered. The consideration of the figures just discussed serve to show very clearly, however, what diverse conclusions may be reached from the very simple conditions assumed.

If we have a certain height to sustain, as S T, Fig. 28, I do not see how the size of the cylinders would modify the amount of pressure, as Mr. Goodrich seems to think it would, outside of the elements of friction between contacts. The relative amount of friction would probably be greater with the small cylinders. Spheres of the same diameter would have more resistance to rolling down than cylinders. Piled as cannon-balls, the points of supporting contact are not in a vertical plane passing through the center.

*Arching Along the Slope.*—I am unable to understand how the edges and corners of a column footing could get more load than the center in a compressible soil. One would naturally expect it to be less. Take a very simple experiment of placing a layer of putty between two blocks. When pressure is applied it flows out and cracks more readily at the corners than at the center of the sides. Certainly there can be nowhere near the pressure developed at the sides, with the material free to flow out, that develops in the center where it is held back by the resistance to flow, of the material surrounding it on the outside. The only possible manner in which I can conceive that the excess side and corner resistance mentioned

could arise, would be in a deep pit of soft material where the weight of the earth develops into a considerable side pressure and bottom heave. That would hardly be anything in the nature of arching, as I look at it.

For an embankment to carry a load at or near the toe greater than the weight of the vertical projection of the material above, would require it to act largely as a beam, from the fact it is not nearly enough of the arch form to produce true arch-reactions. From the very nature of the material, its power to resist shear is very limited and would naturally carry very little of the center load out to the ends of the cross-section or toes of the slopes. To illustrate the point, suppose we construct a cone of fine dry sand. There certainly is nothing apparent in an examination of the mass to lead us to believe that it is controlled by any such laws as were laid down in connection with the explanation of Fig. 12-16. Take out a unit section through the central portion of the cone. Would it not take a wide stretch of the imagination to give it any of the properties or functions of an arch or beam? Consider it under still another treatment. Bring a plane surface to bear on the top of the fine-sand cone. On the peak a very little pressure will cause the sand to flow down the sides and flatten the top. Added loads will produce additional flattening, until the sand cone will carry a highly concentrated load on its flattened top.

The increased resistance to flow is caused very largely by the partially confined particles of sand around the slopes beneath the surface.

*Surface Slopes Super-Surcharge.*—When we put a heavy bank on soil that has not been loaded and which has a tendency to flow or squeeze under load, we may get a certain amount of heaving outside of toes of slope that gives the appearance of the fill having acted as a beam, or arched. Such cases are very noticeable where a fill is made on a peaty or marshy soil. It may and often does develop when soft putty-like clay is loaded with a bank. These are cases where greater pressures should be provided for than would be indicated by the angle of repose of the fill, if soft strata carrying the steeper bank is to be retained. The conditions shown and described in Figs. 10 and 11 are exactly what I have in mind. There the wall is founded in soft clay and holds back a bank of firm material. The extra pressure to be taken care of under those conditions is probably greater than I assumed in working up the data of the paper. The assumptions were not that the underlying soft material was lighter than the solid material above, as Mr. Goodrich's sketch, Fig. 17, would imply. They were assumed to be of some weight. The assumption shown in Fig. 17, where a strata weighing 120 lb. overlies one of 100 lb., is not my idea of surcharge over a soft material. My assumptions are as shown in Fig. 29. Let E A D F be a strata of soft material with a slope of flow A J, 3 to 1. The top

strata B E F C has a slope of flow, E K,  $1\frac{1}{2}$  to 1. (There is no objection to calling it internal friction.) Each weighs 100 lb. per cu. ft. If the surface were level on B G, then the amount of pressure on B A to provide for would be for a material having the flow line 3 to 1. When the surface has full surcharge, B C,  $1\frac{1}{2}$  to 1, the pressure to allow for against B A should be somewhat greater. It is just such conditions as shown in Fig. 29 that give us some of the biggest surprises and most trouble. The behavior of relatively stiff clay itself may be similar to that shown above. At slight depths and pressure the cohesion will maintain it at a relatively steep angle of flow, and little or no lateral pressure is developed. At greater depths and pressure the cohesion is overcome and a great lateral pressure or squeeze is developed. In fact it may be said that the

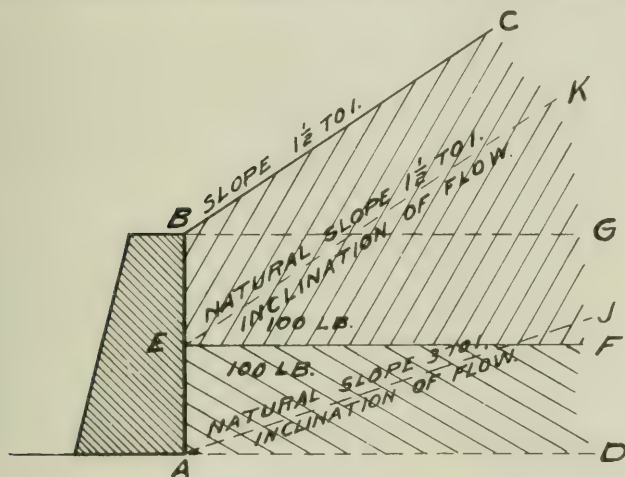


Fig. 29

Fig. 29.—Surcharge greater than angle of repose of underlying strata.

main factor in resistance to flow in sand is friction, while that in clay is cohesion. Friction increases directly with the load applied, while cohesion, when once overcome, offers no added resistance with added weight. Mr. Griffith objects to the term *angle of repose* as ordinarily used. I believe, to designate the slope of a bank by the term *angle of slope* or *surface slope* would be more nearly correct. The ordinary exposed surface slope is usually flatter than a material will stand if the surface is protected from wash, etc. The surface slope is usually determined by loose particles rolling down; lubricated by rain falling on the surface; the action of the wind, frost, etc. Under those conditions the angle of resistance to flow (internal friction) should be much larger than the surface slope would indicate. That is why we can build heavy structures such as piers and

abutments on steep (surcharge) slopes and have them remain perfectly stable.

#### VARIABLE VALUES FOR $\phi$ .

There is no objection to using a variable value of  $\phi$  for the greater depths of a clay bank—use any value at any depth that will give safe and satisfactory results. It is not very material whether  $\phi$  is called the angle of repose; natural slope; internal friction; flow; or, resistance to flow. In selecting a value for any particular case, the effort should be made to learn what effect the most unfavorable conditions are likely to produce, and then provide for them. The earth pressure may be  $0h^2$ ,  $8.6h^2$ ,  $16h^2$ ,  $50h^2$ , or even greater. I would not advise anyone to adhere too closely to the  $16h^2$  or  $15h^2$  rules offered, especially for the hydrostatic pressures that have been mentioned in the discussions.

#### FOUNDATIONS AND DRAINAGE.

The author has never questioned the soundness of good foundations and bank drainage back of the walls. We certainly have it called to our attention often enough. The fact remains the same, that cracked and tipping walls may be considered the rule rather than the exception.

#### MATHEMATICS IN THE PROBLEM.

Mathematics as applied to earth pressure has been held up to scorn. If anyone will give us a better and more rational method of getting results, I for one would be very glad to learn of the right way. It was not love for mathematics, by any means, that induced me to take up this work. I will have to take exception to the inference that the formulæ are abstruse and involved. Unity reduced by the sine of the angle of repose  $\phi$ ,  $1 - \sin \phi$ , is not very difficult. Then that multiplied into the hydrostatic pressure is all there is to it, for vertical back of wall, earth pressure  $E$ .

$$E = \frac{h^2 \gamma}{2} (1 - \sin \phi)$$

The formula for hydrostatic pressure can hardly be simplified. All of the added factors of the formula on page 781 come from the solution of the triangle  $AB S$ , of Fig. 7, to get the weight and effect of the fill carried over the vertical projection of back of wall.

The change in formula to get results for negative back of wall batters may or may not indicate a break-down in the theory, as Mr. Goodrich claims. I would like to call his attention to the platted values in Figs. 4, 5, and 6 and ask if they give the appearance of break-downs. Compare with Rankine and Rebhann in the same figures.

While for level fill back of wall the values given by the method I have employed are larger than those given by Rankine and Rebhann, still the resistance to flow (internal friction) should usually

be taken larger than the weathered surface slope for any given material.

For instance, a weathered surface slope  $1\frac{1}{2}$  to 1 may easily have the resistance to flow of  $1\frac{1}{4}$  to 1, or 1 to 1. At any rate we should choose  $\phi$  so as to give large enough pressure  $E$ .

As I have said, I would be only too glad to see arrangements made for carrying out a series of experiments and tests on a large scale to get exact values as near as may be, and establish a sound basis from which to work.

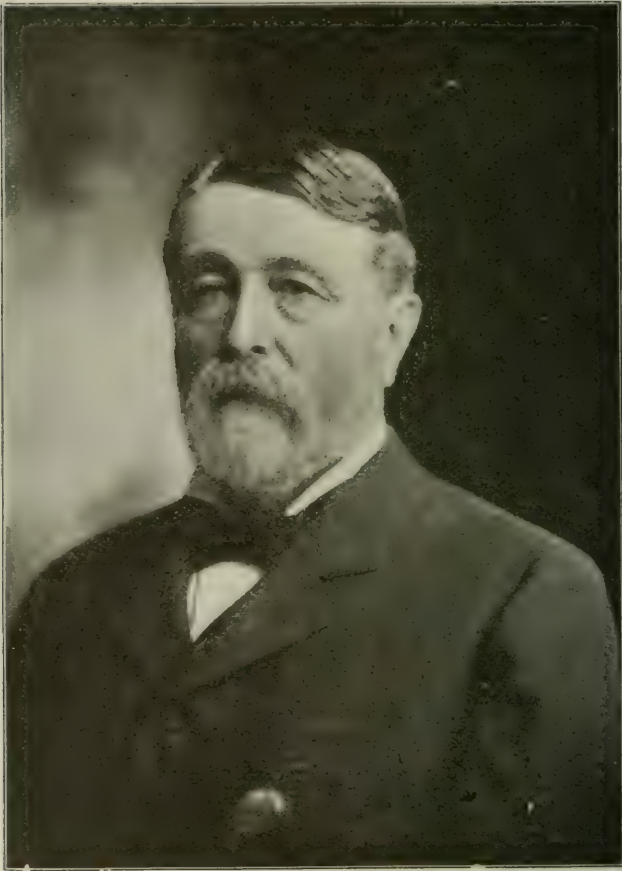
#### BACK OF WALL FRICTION.

I might say, outside of any points raised in the paper or discussion, that I believe the so-called back of wall friction should be neglected. It may or may not exist. If it does exist, let it go as a factor favorable to increased stability. As a factor in determining the direction of the resultant, I believe it can well be neglected in wall designs. In bins, where material is withdrawn from the bottom, friction against the sides unquestionably is a factor. On account of the compressibility of the bin contents, friction may develop to the full extent before material is withdrawn. See page 781.

#### CONCLUSION.

This discussion has run on to considerable length. My only excuse for taking the matter up as I have was the hope that enough interest might be aroused in the subject to lead to more consistent and satisfactory results, not only for earth pressure data but, as a logical sequence, better wall designs. I think you will all agree that there is room for much improvement. With the splendid results the engineering profession has accomplished in other fields of research and design, we should not be satisfied until we make a good showing in the one we have been considering. *Get better results in the future than we have in the past.*

## IN MEMORIAM.



**RICHARD PRICE MORGAN**

**Died May 20, 1910.**

At the Hahnemann Hospital in Chicago, on the morning of May 20, 1910, the long, honorable and useful career of Richard Price Morgan ended in "the sleep which knows no waking." He was born at Stockbridge, Massachusetts, September 17, 1828, and was married to Miss Mary Rutzer in Poughkeepsie, New York, November 1, 1854, who died on the 8th day of August, 1877.

On Sunday, May 22, he was laid to rest in the family lot of the cemetery near Dwight, Illinois. Many were the friends and admirers of this good man, who joined his sons and his kindred

in paying their last tribute of love and respect by participating in the solemn burial services.

Hard by the place where they laid him was a headstone inscribed "Richard Price Morgan, civil engineer," marking the resting place of the father of this latest comer to "God's Acre"—a father whom he honored in his heart and by his life.

Choosing his father's profession, his first work therein was on the preliminary surveys, location and construction of the Hudson River Railroad, from 1847 to 1852. On that work he served with our honored member, the late Octave Chanute, and under another of our honored members, the late Oliver B. Green. The call of the West brought him to Illinois to take charge of the location and construction of the Chicago and Mississippi Railroad, now the Chicago and Alton Railway; he made his headquarters at Bloomington. Before the completion of the road he was made its general superintendent, continuing in that capacity until 1857, when the ownership of the property changed. During his residence in Bloomington his kindness of heart led him, at a time when the city was crowded, to share his room with a stranger who was later to become one of the colossal personalities in the history of his country. That incident made Mr. Lincoln and Mr. Morgan friends in the truest sense because each recognized the worth of the other. From 1857 to 1860 Mr. Morgan engaged in farming and laid out the town of Dwight. From 1860 to 1869 he was engaged in making surveys for projected lines of railway. He became interested in rapid transit for cities and perfected plans for an elevated railroad for the New York Rapid Transit Commission. In competition with seventeen other designs submitted to the American Society of Civil Engineers, his design stood first in practicability and merit. The Centennial Exposition in Philadelphia in 1876 awarded him diplomas and medals for his original research in the realm of rapid transit for cities, and afterwards the merit of his work was recognized by the Exposition of Railway Appliances held at Chicago in 1884.

Mr. Morgan became chief engineer of the Lafayette and Bloomington Railroad, now a part of the Erie System, in 1870. Governor John M. Palmer appointed him on the first Board of Railroad and Warehouse Commissioners of the State of Illinois. He personally advanced the money which carried the famous Lexington case through the courts, establishing the principle by which the public carriers were prohibited from charging more for a short haul than for a long one. This principle, later, became incorporated in the acts regulating interstate commerce, about which congressional committees dealing with these questions frequently consulted Mr. Morgan.

"With the beginning of the consolidation of railway properties into large systems," Mr. Morgan turned his familiarity

with the creation and value of such properties to good account; and his counsel was sought by capitalists who desired sound and reliable advice about the roads which they proposed to acquire and amalgamate.

In 1887 he was appointed chief engineer of the United States Pacific Railway Commission, and he made the estimates of their value and the cost of reproducing the properties of those bond-aided roads included in the Union and Central Pacific systems. Guided by these estimates, the government made its final settlement with those roads for the aid by which it had enabled them to build. This service was followed by independent reports upon the value of the physical properties and earning capacity of the principal railway lines west of the Mississippi River between Canada and Mexico.

In 1891 Mr. Morgan was elected a trustee of the University of Illinois, and discharged the duties of that trust with high intelligence and great zeal. He never wavered in his loyal devotion to that great institution. How his service was appreciated is shown by the fact that in 1893 the university conferred upon him the degree of Doctor of Engineering.

In 1893 he was engaged by the Railroad and Warehouse Commission of California to prepare a report upon the reasonableness of transportation charges in that state.

In 1896 he was appointed by President Cleveland a member of a board, composed of military and civil engineers and a naval officer, to select a location and prepare plans and estimates for a deep water harbor on the southern coast of California. In this same year, too, he made investigations for the Commerce Commission of the State of New York regarding the causes of the decline of commerce in the port of New York, with recommendations pointing to its restoration and increase.

In 1860 when the then Prince of Wales—the late King Edward VII—visited America, he made a hunting trip to Illinois and, with his retinue, was the guest of Mr. Morgan and Mr. James Clinton Spencer. Of that distinguished company the King was the last survivor, and he passed away only a few days before the passing of his democratic host. Mr. Morgan had been urged by one whose labors and whose merits had won for him knighthood at the hands of the King, to visit England and meet the sovereign who remembered the hospitalities extended to him nearly fifty years before, and had expressed a desire to see his host once more.

My warm personal friendship for the subject of this sketch dates back to 1891, when we served together, he as chairman and I as secretary, of a commission appointed by this society to investigate and report upon the terminal problems of the city of Chicago, both rail and water.

This brief outline serves only as a suggestion of the life's

work which he performed so well; but it gives no suggestion of the man as we knew and admired him for qualities of heart and mind which were steeped in human kindness and exalted by Christian faith.

He was a man who had been brought into close touch with life's rough side without becoming roughened by it. In all of the years of our intimate acquaintance I never heard him utter a coarse word or had reason to think that he harbored a coarse thought.

The conversation of a man mentally equipped as he was and with his store of varied experiences to draw from was interesting in the extreme and correspondingly instructive.

Richard Price Morgan did honor to the engineering profession, and the knowledge that he was one of us should be a source of satisfaction to every member of the Western Society of Engineers. Such names upon our roll make it indeed a *Roll of Honor*.

ISHAM RANDOLPH,

Committee.

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**SAMUEL M. ROWE, M. W. S. E.**

**Died May 22, 1910.**

Samuel M. Rowe was born in Dearborn County, Indiana, February 8, 1831. He came to La Salle County Illinois, in about 1842, and lived upon the spot where the town of Sheridan is now located. Prior to the Civil War he was a surveyor in and about that locality.

In 1868 he located the line of what was then the Ottawa, Oswego and Fox River Valley Railroad.

In 1869 and 1870 he was a member of the firm of Rowe & Jackson, engaged in the work of constructing the above line.

In 1872 Mr. Rowe became associated with Dr. J. R. Zearing, under the firm name of Rowe & Zearing, who engaged in the construction of the Texas Pacific Railroad from Dallas, Texas, eastward about seventy-five miles to Longview. In 1874 they were awarded the contract for the construction of a railroad bridge across the Trinity River at Dallas, Texas, and they also extended the track ten miles west of Dallas. In the summer of that year they moved to Sherman, Texas, and commenced to build the track of the Trans-Continental Line, laying track to a point about eighty miles east of Sherman. Shifting to Texarkana, they built the Trans-Continental Line westward, connecting with the line they had built from the west.

In 1875, the firm (Rowe & Zearing) was engaged in construction work on the Orleans and Pacific Railroad.

Somewhat later, or about 1878, Mr. Rowe was engaged by the Santa Fe Railroad in connection with track laying, etc., near

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Florence, Kansas. From the latter part of 1878 until about 1880 or 1881, he was engaged as engineer in charge of water service on the New Mexico extension of the Santa Fe road from La Junta south.

In 1882 Mr. Rowe was resident engineer at Las Vegas, and while acting in this capacity was, in 1885, put in charge of the construction and operation of the timber preserving plant at Las Vegas, New Mexico.

Early in 1887 he was appointed chief engineer of the Atlantic and Pacific Railroad. While in that position the "Red Rock" bridge across the Colorado River at Needles, California, was built under his supervision.

In 1891 Mr. Rowe came to Chicago and organized the firm of Rowe & Rowe, consulting engineers. The firm consisted of Mr. Samuel M. Rowe and his son, Robert D. Rowe.

From 1891 to the time of his death Mr. Rowe was engaged in work connected with the preservation of timber, and his handbook on this subject is the result of about twenty-five years of careful and exhaustive study and practice. He labored to perfect the methods and appliances, studying each principle connected with the operation of timber preserving. His business was to design and install timber-preserving plants, making plans and specifications for same, supervising the construction, and inspecting the work. About twenty-seven timber-preserving plants have been constructed, for which he either furnished plans and specifications or had supervision of the installation, in most cases doing both the planning and supervising. Work for the most part was done for the various railroad companies of this country and Mexico. In this connection he was employed by the United States Government in the capacity of expert in the forestry service, devoting a part of his time to this work during 1905-6-7.

He was associated with Dr. J. A. L. Waddell during the construction of the South Halsted street lift bridge over the South Branch of the Chicago River, which was completed about 1894.

Mr. Rowe made a careful study of the subway question as related to Chicago, and did considerable amount of work in connection with the subway and harbor enterprises. Later he became a director and officer of the Chicago Subway, Arcade and Traction Company, and was connected with and active in this company up to the time of his death; in fact, he attended a meeting of the company only a day or so before his final illness, which lasted about ten days.

Until the time of his death, Mr. Rowe was an active man, taking part in business affairs. He was an actual witness to the wonderful growth of the city of Chicago, from a town of a

few thousand inhabitants to a metropolis of about 2,500,000 people, and always took an active interest in, and had a thorough understanding of the civic problems that confronted this city.

He died of pneumonia May 22, 1910, and was buried at Sheridan, La Salle County, Illinois.

**FREDERICK SEYMOUR SHEWELL, M. W. S. E.**

**Died January 10, 1910.**

Frederick Seymour Shewell was born at Hinsdale, Illinois, December 30, 1875, and died at the same place January 10, 1910, after a prolonged illness of six months.

For so young a man his work in the lines of engineering followed by him had been important and varied, though starting with only such acquired qualifications as were afforded by a course at the Chicago Manual Training School, from which he graduated in 1897.

He was employed as instrument man and topographer on railroad work, and with the Michigan Geological Survey; also as draftsman during his vacations. After graduation at the Manual Training School he was employed as draftsman for the Bucyrus company, and the Marion Steam Shovel Company, on steam shovel and dredge design.

Subsequently he took a course at the Michigan College of Mines, Houghton, Michigan. After leaving the College of Mines, in 1902, he was employed by the city of Chicago in the design of the large controlling gates for the Thirty-ninth street sewage pumping plant.

He then spent more than a year in Mexico in mining affairs, after which he was again employed by the city of Chicago in designing the coal handling machinery for the Thirty-ninth street pumping station. He also prepared plans for the gates at the Lawrence avenue sewage pumping station.

In his work for the city he displayed much ability and originality of design, for which he is entitled to much credit.

Subsequently he was engaged in laying out the townsite of Indiana Harbor.

December 28, 1905, he was married to Florence G. Gourdeau, of Ishpeming, Michigan, soon after which event he returned to Mexico as chief engineer for the Guanajuato Developing Company, Guanajuato, Mexico. A part of his work here was furnishing water to all of the company's mills from a storage reservoir.

He was also in business for himself as consulting engineer at Guanajuato for a time, and subsequently was chief engineer of the mines and mills of the Cia de Real del Monte of Pachuca, Mexico. This work included the hydraulic work connected with

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their water supply, and the construction of two large modern cyanide mills, and other matters pertaining to the equipment and operation of their mines.

His last work, shortly before his death, was in Phoenix, Arizona, where he was engaged in the examination of water power and electric road matters, and the mining and milling conditions of the Cave Creek and Winifred Mining Districts of Maricopa County.

In all of his work he showed much engineering ability; particularly so in the design and construction of the cyanide mills for the Mexican companies, which consisted of five large plants, aggregating 940 tons daily capacity.

Mr. Shewell's ambition and energy, combined with his faculty for making warm friends, gave great promise of future usefulness.

BENEZETTE WILLIAMS,  
Committee.

# PROCEEDINGS OF THE SOCIETY.

## ABSTRACT OF MINUTES OF MEETINGS.

*Wednesday, Oct. 26, 1910.*—Extra meeting (No. 717) called to order at 8:20 p. m., President Alvord presiding and 50 members and guests in attendance. The president called attention that the next following meeting to be held Nov. 2, would be a regular meeting at which time certain amendments to the Constitution and By-Laws would be up for consideration and discussion. Gordon F. Dodge, M. W. S. E., was introduced who read his paper on The Use of Diagrams for Solving Engineering Formulae. Discussion followed from Messrs. Winslow, Armstrong, Moseley, DeWolfe, Talbot, and the author. Adjourned at 10 p. m.

*Wednesday, Nov. 2, 1910.*—Regular meeting (No. 718). Called to order at 8:30 p. m. with Vice-President Bement presiding and 30 members and guests present. Reading of minutes of previous meetings omitted, but approved as printed. Secretary reported from the Board of Direction the following list of applicants for membership:

Edward L. Lahey, Chicago.  
Gustav A. Stanton, Chicago.  
John Ensink, Chicago.  
Paul L. Battey, Chicago.  
Douglas Graham, Chicago, transfer.  
Ernst J. Berg, Urbana, Ill.  
James L. Coombes, Chicago.  
William Banne, Chicago.  
Herbert L. St. John, Chicago.  
Stephen P. Bewick, Kansas City, Mo.  
Wm. E. Barnett, Chicago.  
Chester H. Dalrymple, Chicago.

and that the Board had elected into Active membership:

Bruno E. Ahlskog, Chicago.  
Langdon Pearse, Chicago.  
John M. Davidson, Gary, Ind.  
Edwin Hancock, Jr., La Grange, Ill.

The secretary announced the death, Sept. 18th, of Charles L. Gould, Member. The subject, the amendments to the Constitution and By-Laws, was explained by the chairman and discussed by Andrews Allen at some length, and by others. The amendments were ordered to be carefully edited and submitted to vote of the Active members of the Society, by letter-ballot, the result of such ballot to be announced to the Society at the next regular meeting, Dec. 7, 1910. Adjourned 10:30 p. m.

*Wednesday, Nov. 9, 1910.*—Extra meeting (No. 719). Bridge and Structural Section; called to order 8:30 p. m. with W. C. Armstrong, vice-chairman, presiding, and 80 members and guests in attendance. The secretary read the paper on Wind Loads on Mill Building Bents, by Prof. Albert Smith, of Lafayette, Ind. Discussion followed from Messrs. Reichmann, Davidson, Smetters, Armstrong, Walker, Mohler, Gerety, Kellogg, Williams, Kyles, McCullough, and Prof. Smith. Adjourned 9:50 p. m.

*Wednesday, Nov. 16, 1910.*—Extra meeting (No. 720) called to order at 8:10 p. m. with Vice-President Chamberlain presiding and about 40 members and guests in attendance. An informal meeting for a talk about the Dolese and Shepard plants at Hawthorne, and Gary, Ill., which had been visited by an excursion party that day. A history of the Gary plant

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and its development and operation was given by Messrs. J. C. Buckbee, H. E. Bachtenkircher, F. E. Woodford, and George W. Patnoc, who were, or had been, connected with the company. Meeting adjourned at 10:30 p. m.

*Wednesday, Nov. 23, 1910.*—Extra meeting (No. 721) being a joint-meeting of the Electrical Section and the Chicago Section, A. I. E. E., was called to order at 8:20 p. m. with Chairman G. H. Lukes presiding and about 135 members and guests in attendance. Dr. Ernst J. Berg, U. of I., Urbana, Ill., was introduced who presented his paper on the Surging of Synchronous Machines. Discussion followed from Messrs. Lyman, Junkersfeld, Dudley, Roper, Jackson, Hecht, Cravens, Brady, Carroll, Pardee, Symons, Hirt and closure from Dr. Berg. Adjourned at 10:00 p. m.

*Wednesday, Nov. 30, 1910.*—Extra meeting (No. 722) called to order at 8:25 p. m. with Mr. Reichmann presiding and about 100 members and guests including many ladies, in attendance. Mr. W. R. Patterson was introduced, who gave an informal travelogue with stereopticon illustrations—A Trip to Hong Kong—which was much appreciated. Meeting adjourned at 9:30 p. m.

*Wednesday, December 7, 1910.*—Regular meeting (No. 723) called to order at 8:15 p. m., Vice-President Chamberlain presiding and 50 members and guests in attendance. Minutes of preceding meeting read and approved. Reported from the Board of Direction that on petition, D. J. Whittemore, for 38 years a member, had been elected an honorary member. That applications for membership had been received from the following:

Harry D. Sues, Chicago.  
James C. Pinney, Milwaukee, Wis.  
Wm. F. Jordan, Chicago.  
Herbert H. Evans, Chicago.  
Thomas A. Jordan, Chicago.  
Gustav A. Haggander, Chicago.  
George E. Cadman, Chicago.  
Harry B. Kirkland, Chicago.  
John F. Cushing, Chicago.  
Elmer T. Howson, Chicago.  
Wm. J. Miskella, Chicago, transfer.  
Donald C. Barrett, Pierre, S. D.  
Justus B. Eddy, Chicago.  
Frank M. Smith, Mishawaka, Ind.  
James S. Adams, Oak Park, Ill.  
Bert E. Strohm, Chicago.  
John E. McNichols, Chicago.  
Hugh J. Fixmer, Chicago, transfer.

That the following had been elected into membership:

Orville H. Drought, Chicago.....	Junior.
L. V. Fraley, Chicago.....	Active.
Geo. C. D. Lenth, Chicago.....	Active.
Edward L. Lahey, Chicago.....	Associate.
John Ensink, Chicago.....	Active.
Paul L. Battey, Chicago.....	Active.
Douglas Graham, Chicago, transfer.....	Active.
Ernst J. Berg, Urbana, Ill.....	Active.
James L. Coombes, Chicago.....	Active.
William Banne, Chicago.....	Junior.
Herbert L. St. John, Chicago.....	Active.

That the canvass of the vote of acceptance of the new Constitution had been 182 affirmative votes against 16 negative votes. The new Constitution was adopted, to be effective January 11, 1911. The nomination by petition of candidates for officers of the Society resulted in the following nominations:

For president: O. P. Chamberlain and P. Junkersfeld.  
 For first vice-president: W. C. Armstrong and A. Bement.  
 For second vice-president: C. R. Dart and G. T. Seely.  
 For third vice-president: Ira O. Baker and John F. Hayford.  
 For treasurer: A. Reichmann.

For trustees to serve three years: W. M. Hughes, E. McCullough, and M. K. Trumbull.

Announcement was made of the death of Past-President O. Chanut, November 23, 1910. The secretary read the paper for the evening on Entropy, written by Prof. G. A. Goodenough, U. of I., Urbana, Ill. Discussion followed from Messrs. Bement, Abbott, Wilson, P. M. Chamberlain, Samson, Kuss, and the chairman. Adjourned at 10:10 p. m.

*Wednesday, December 14, 1910.*—Extra meeting (No. 724). Bridge and Structural Section, called to order 8:15 p. m.; T. L. Condron, chairman, presiding, and 55 members and guests in attendance. Minutes of previous meeting read and approved. Nominations made for Executive Committee for next year as follows:

Chairman: W. C. Armstrong and C. R. Dart.  
 Vice-chairman: F. E. Davidson and L. J. Hotchkiss.  
 Directors: W. H. Alderson, I. L. Simmons, and I. F. Stern.

W. H. Alderson was introduced, who presented his paper on the Reconstruction of the Pecos Viaduct. Discussion followed from Messrs. Andrews Allen, W. C. Armstrong, I. F. Stern, and others. Adjourned at 10:15 p. m.

*Wednesday, December 21, 1910.*—Extra meeting (No. 725) Hydraulic, Sanitary, and Municipal Section. Called to order at 8:20 p. m.; John Ericson, chairman; in Fullerton Hall, the Art Institute. About 100 present including many ladies. Mr. E. H. Bennett was introduced, who presented The Chicago Plan, with many beautiful stereopticon views. Adjourned at 9:45 p. m.

## EXCURSION.

**November 16, 1910.**

The Dolese & Shepard Co. of Chicago, invited the Western Society of Engineers to visit the limestone quarries and accessories at their plants at Hawthorne and Gary, Ill., on Wednesday, November 16, 1910. A special train was provided for this excursion, which left the Union Station, Chicago, about 1:30 p. m. There were about 100 in the party, who were under the guidance of officers of the company.

The first stop was at Hawthorne, where a large part of the output of the quarry is burned in continuous kilns, and supplied to their customers as quick-lime. A considerable portion, however, is marketed under the trade name of limene, which is hydrated lime, and shipped out as a fine powder ready for mixing into mortar. While at the quarry, which is now about 175 ft. deep, a large blast was fired, and very successfully, resulting in a great mass of broken-down rock ready to be loaded into the cars. This quarry has been in operation for many years.

The party was then conveyed to Gary, Ill., about 18 miles from Chicago, over the C. & I. W. R. R. The works here are much more  
 December, 1910

extensive and of more recent development than at Hawthorne. There are about 300 acres in the property underlaid by Niagara limestone, of which about 130 acres are available for quarry purposes. The rock formation has been tested by drill-holes to a depth of 150 ft. The quarry, as now open, covers an area of about 21 acres and has been worked down to a depth of 40 ft. The drilling for the blasting-holes is done by well-drilling machines which have proved superior to the ordinary air-drill mounted on a tripod. The blast-holes drilled by these machines are between 5 and 6 in. in diameter and about 40 ft. deep. With these large holes, only about one-third as many as in the earlier practice are required for breaking down the rock, which is then picked up by steam-shovels and loaded into electric cars of 12 cu. yds. capacity. The cars are equipped with two 30 H. P. electric D. C. motors working at 220 volts and provided with automatic brakes. On the down grade the motors are reversed and thus act as a brake, the energy being dissipated in heat. The movement of these cars, independently of each other, or of motor-men on the cars, is regulated from a tower-house on the bank overlooking the quarry. The electric energy is conveyed to the car motors by means of a third rail placed centrally between the main-track rails. This third-rail is cut into sections, any one of which can be energized at will by the operator in the tower-house. When so energized the direct current is given to the motors, which immediately move the cars that may be on that section. It was very interesting to those on the excursion to view the quarry from some elevated point of observation and note the movement of the cars here and there in the quarry and then start up the long incline leading out of the quarry up to the discharging level of the crusher-house, without any attendants on the cars. This electric third-rail system is the work of The Woodford Electric Co., of Chicago.

On the route out of the quarry to the crusher-house the cars pass over a track-scale and the load is automatically weighed and the weight printed on a moving paper-tape, so an accurate record is kept day by day of the tonnage of rock taken out of the quarry. The number of the steam-shovel loading the cars is also kept with this record of car weights, so a complete check is kept of the work done, showing the efficiency of the plant in its several parts.

The crusher-house contains an immense gyratory crusher capable of taking pieces of rock as large as 43 in. across and has a capacity of 6,000 cu. yds. of rock in 10 hours. Some large buildings, containing the screening and conveying machinery and large bins for storage, were visited by the party, who found much interest in the process of separation, conveying, and storing of the materials of different degrees of fineness, ready to be delivered into the cars for shipment in accordance with the demands of the customers.

Electrical energy is supplied by the Economy Light and Power Co., of Joliet, at a high voltage and reduced to the required voltage for the service required by transformers in a suitably equipped sub-station.

The rock may be shipped in large sizes about 6 in. across, for use in blast-furnace operation as a flux, for which there is a considerable demand, or finer crushed rock of different sizes for concrete work, for macadam, road material, etc., can be supplied from the storage bins according to daily demands. Some conveying from one point to another is done by chain belts and buckets, and in other places the crushed rock is conveyed by belt conveyors. The whole plant is admirably planned and is operated to a high degree of efficiency, which is largely due to the inventive genius of Mr. George W. Patnoe, master mechanic and general superintendent of the company.

A meeting of the society was held in the evening of the same day in

the Society Rooms, when an informal discussion of various parts of the plant was presented by Messrs. J. C. Buckbee, F. E. Woodford, George W. Patnoe, and H. E. Bachtenkircher (chemist of the Hawthorne plant).

To Mr. A. V. Konsberg, one of the officers of the company, great credit is due for his efforts on behalf of the excursion party to give all a good time. Luncheon was served on the train, which was very acceptable and thanks are due to all of these for what they did for the comfort and pleasure of the party.

## BOOK REVIEWS.

THE CONSERVATION OF NATURAL RESOURCES IN THE UNITED STATES. By Charles R. Van Hise. The Macmillan Company, New York, 1910. Cloth; 5½ by 8 in.; 413 pages; numerous plates and illustrations. Price, \$2.00.

This book is a timely one and presents to the reader, in very convenient form, a summary of the subject which is well written and very interesting. The material of the book was originally a series of lectures to the students of the University of Wisconsin, though the style of the text of this volume does not show its lecture-room origin. Many sources have been drawn upon by the author for the matter of the book, including the large, three-volume report of the National Conservation Commission, and the general reader is under obligations to Prof. Van Hise for his skill and industry in so collecting and conserving the information from so many sources.

The book opens with a brief introduction and history of the conservation movement, and this is followed by the main body of the book divided into five parts: I, The Mineral Resources; II, Water; III, Forests; IV, The Land; and V, Conservation and Mankind. Three appendices conclude the book; these are: I, Declaration of Governors for Conservation of Natural Resources; II, North American Conservation Conference, and III, National Conservation Association. These are of value as concluding the history of this modern movement.

The four main divisions of the book include reviews, descriptive and with statistics, which exhibit the wastes which occur in the practical utilization of the resources of the earth, for man's use. This includes some conjectures as to the exhaustion of such resources which cannot be replaced by man's efforts, as coal, petroleum, natural gas, iron ore, etc. The source of the water supply is the atmospheric moisture in the way of rain or snow, and this amount is subdivided into the Fly-off, the Cut-off, and the Run-off, and due consideration is given to Water Powers, Navigation, and Irrigation, and the conserving of these resources. Forests and The Land are also reviewed and commented upon in an instructive manner. Most people are familiar with the statement that some lands are worn out and will not now raise the crops that have been obtained because of this loss of fertility. This is of great importance—the conservation of fertility, or the replacement of these elements needed for plant development. Phosphorous is one of these elements of great importance, which means the curtailment of the exportation to other countries of the phosphate rock which should be retained for our own farms.

A valuable feature is the foot-notes and references to the sources of information used by the author, and are of value to the reader who may wish to go to the original papers. Taken all-in-all, the book is a very valuable one and deserves a wide circulation and careful reading.

W.

**DEFORMATION OF RAILROAD TRACKS, and the Means of Remedying Them.** By G. Cuenot, Chief Engineer of Bridges and Highways, attached to the Board of Control of the Paris-Lyons-Mediterranean Ry. Translation by W. C. Cushing, Chief Engineer of Maintenance of Way, Pennsylvania Lines (Southwest System). *The Railroad Gazette*, New York and Chicago. Cloth; 6 by 9 in.; pp. 147; 35 illustrations. Price, \$2.00.

The scientific study of railway track has been followed out much more extensively in Europe than in this country, and a feature of this study is the consideration of the track as a unit structure independently of the consideration of the design of its individual parts. Mr. Cuenot points out that the track construction should be in proper relation to the loads carried and the speed of the trains, and that if these factors are increased the strength of the track should be increased correspondingly. The experiments and investigations which are described in this book were made as a result of instructions from the Minister of Public Works to make experiments with a composite tie composed of wood and steel. Mr. Cuenot did not consider it sufficient to place ties in the track and simply observe the manner in which they behaved. On the contrary, he considered it necessary to examine what takes place in track of normal construction and to compare the results with those found in track laid with the special ties.

The dimensions of ties, their spacing, the tamping of the ballast, the longitudinal deflection and movement of the track under passing trains, the transverse bending of the ties, the efficiency of rail fastenings and rail joints, are all dealt with, not so much as individual problems but rather as factors of the one problem of track design. Special apparatus was devised to show the movements of ties under loads, and also to determine the resisting power of screw spikes against vertical and lateral forces.

For track carrying heavy and high-speed traffic the following features are considered necessary: (1) extremely rigid ties, excluding steel ties of trough section; (2) the use of a tie under each rail joint, with shoulder ties 12 in. distant; (3) the use of steel tie-plates having ribs to support the back of the mushroom head of the screw spike. As to the composite tie, this is considered to present advantages. Its design (as modified) consists of a pair of steel channels or tee-bars clamped together and having rail-bearing blocks fitted between them.

The book deals with a subject of importance to American railways and to engineers of maintenance-of-way. It is written (and translated) in an interesting and readable style, and not merely as a dry report upon certain experiments. It shows very clearly that the track is a unit structure, and that it cannot be strengthened efficiently by simply improving some one element of its construction.

E. E. R. T.

**CONSTRUCTION AND MAINTENANCE OF RAILWAY ROADBED AND TRACK.** By Frederick J. Prior. Frederick J. Drake & Co., Chicago. 569 pages and index; 4½ by 6½ in.; many illustrations; flexible leather. Price \$2.00.

So much has already been written in regard to railway location, construction, and maintenance that it is now possible to make a good book on this subject by intelligent selection from existing works. This book is avowedly a compilation. No claim is made to originality, the humble title of "Compiler" being signed to the preface. The work is made up largely of direct quotations, but a certain amount of rewriting and rearranging was done in order to make the material suitable for a book of this size and character.

Intelligence in selection is doubtless the vital thing in a book of this kind, and the compiler seems to have exercised good judgment in this

particular. The chapter on location and construction, for instance, is made up almost entirely from the well-known work on that subject by John R. Stephens; while the chapter on maintenance is composed largely of quotations from the published writings of leading railway engineers. It was inevitable, no doubt, that a book made in this way should be lacking in unity, and that it should impress the reader as being several separate books rather than one book. Location, construction, maintenance, and railway structures are discussed in detail, accompanied by a sufficient number of illustrations. In the appendix are curve tables, earthwork tables, a chapter on concrete, and many illustrations of engineering instruments and of track tools and equipment.

J. E. M.

THE AGE OF MAMMALS, in Europe, Asia, and North America. By Prof. Henry F. Osborn, of Columbia University and Curator of American Museum of Natural History. 635 pages, including index and appendix;  $6\frac{1}{2}$  by  $9\frac{1}{4}$  in.; 220 figures, including some folding maps Macmillan Co., New York, 1910. Cloth. Price, \$4.50.

Chapter I, Introduction, covering Philosophy of Structure of Mammals; II, Mammals and their Environments; III, Geographic or Space Distribution; IV, Geologic or Time Distribution; V, Duration of Age of Mammals; VI, World Supply of Mammals, and VII, Palaeogeography.

Chapter II, the Eocene:—Palaeogeography of Eocene Europe and of North America; Late Cretaceous and Early Eocene Flora; Alternate Union and Disunion of European and North American Life; I, Basal Eocene; II, Lower Eocene, and III, Middle and Upper Eocene Life in Europe and North America.

Chapter III, Oligocene:—The Fourth Faunal Phase; Palaeogeography; Flora and Climate, and Physiographic Conditions: I, Oligocene Life of Europe; II, Upper Eocene, and III, Oligocene Life of America.

Chapter IV, The Miocene:—Fifth Faunal Phase; Flora and Climate of Europe; Continental Connections; Physiographic Changes in Europe, and Miocene Life of Europe and America Compared, consisting of: I, Miocene Life of Europe; II, Middle Miocene Life of Asia, and III, Miocene Life of North America.

Chapter V, The Pliocene:—Sixth Faunal Phase, consisting of I, Pliocene Life of Europe; II, Pliocene Life of Asia; III, Pliocene Life of North America.

Chapter VI, The Pleistocene:—Seventh Faunal Phase, covering I, Pleistocene Life of Europe; II, Pleistocene Life of North Africa; III, Pleistocene Life of North America.

In conclusion is presented:—Antiquity of Man in North America, and Causes of Pleistocene Extinction.

The book is a remarkable contribution to geological knowledge. For its satisfactory and intelligent reading, some knowledge of geology and geologic terms is necessary, with an understanding of the various ages and horizons into which geologic formations are divided. "Time and place are the main theme of the work," as it is a study of the sources or birthplaces of the several kinds of mammals, their competitions, migrations, and extinctions. Necessarily associated with these is a study of physical geography of the earth, with its changes and modifications due to elevation above, and submergence beneath ocean areas. The many illustrations are admirable, whether as maps showing such changes in the earth surface and the places of discovery of mammalian remains, or as pictures of the ancient fauna, as "restored" by Charles K. Knight, of the American Museum of Natural History.

W.

HANDBOOK FOR HEATING AND VENTILATING ENGINEERS. By James D. Hoffman, M. E., Professor of Engineering Design, assisted by Benjamin F. Raber, Instructor in Engineering Design, Purdue University, Lafayette, Ind., 1910. Flexible leather; 4½ by 6¾ in.; 322 pages, including in lex, with many illustrations, diagrams, and tables. Price, \$3.50.

This is a convenient handbook containing many conversion tables as well as a statement of the principles and facts needed in his daily work by a heating and ventilating engineer. The work consists of seventeen chapters. These subdivisions relate first to Heat, Air, and Heat Losses; chapters IV and V are on Furnace Heating; VI, VII, and VIII are on Hot Water and Steam Heating; chapters IX, X, and XI relate to Mechanical Warm Air Heating, and XII on Mechanical Vacuum Heating. District Heating occupies chapter XIII, while Temperature Control is the subject of chapter XIV, and Electrical Heating of chapter XV. A Course of Instruction and Typical and Comprehensive Specifications, are the subjects of chapters XVI and XVII.

A valuable feature of the book is the reference to sources of information, or credit for tables, authorities quoted, etc., given throughout the text, and also references to technical books and publications at the end of sundry chapters. This will enable the user of the book to get additional information on the subjects previously considered. The features of Courses of Instruction, as given in chapter XVI, and outlines or forms of specifications in chapter XVII, are very valuable. But it is to be regretted that to secure the small, handy, pocket-size of the book, the illustrations have been so reduced, as frequently to lack clearness and thus making them less valuable. A mass of valuable and handy tables, constituting some 40 pages in an appendix, closes the book which is a welcome addition to our engineering literature on heating and ventilating.

## LIBRARY NOTES.

The Library Committee desires to return its thanks for donations to the Library. Since the last publications of the list of such gifts, the following publications have been received:

### MISCELLANEOUS GIFTS.

E. E. R. Tratman, M. W. S. E.—

Water Supply and Irrigation Papers Nos. 237, 239, 245-251.

Proceedings 2d Annual Convention International Railway Fuel Association, 1910. Pam.

The Telephone for Train Dispatching, W. E. Harkness. Pam.

Train Dispatching by Telephone, C. H. Gaunt. Pam. University of Illinois Bulletin, No. 41. Pam.

Proceedings, Association of Transportation and Car Accounting Officers, June, 1910. Pam.

Bulletin 11, National Society for the Promotion of Industrial Education. Pam.

Annual Report, Board of Public Works, Ohio, 1909. Pam.

Story of the Western Pacific Railway. Pam.

Illinois Geological Survey, Bulletin 15. Cloth.

Gravel vs. Limestone Screenings for Concrete. Pam.

Farm and Cement News. Pam.

- Report of General Manager of Railways of Cape of Good Hope, 1909.  
 Report of Chief Commissioner of Railways of New South Wales, 1910.  
 Administration Report of the Railways in India, 1909.  
 Fourth Annual Report, Railroad Commission of Indiana, 1909. Cloth.  
 Cours de Mechanique, L. Guillot. Cloth.  
 Guide de L'Adjusteur, Jules Merlot. Cloth.
- Charles L. Strobel, M. W. S. E., Chicago—  
 Various Reports of National Monetary Commission. Pams.
- McGraw-Hill Book Co.—  
 The Construction of Graphical Charts, J. B. Peddle. Cloth.
- New Orleans Sewerage and Water Board—  
 21st Semi-Annual Report, 1910. Pam.
- The Macmillan Co.—  
 The Age of Mammals, Henry F. Osborn. Cloth.
- Albert T. Canfield, M. W. S. E.—  
 Reports of Board of Park Commissioners, Kansas City, Mo. Pams.
- Charles Mulford Robinson—  
 The Improvement of Ft. Wayne, Ind. Pam.
- Sir Edwin Dunning-Lawrence, Bart, London—  
 Bacon is Shakespeare, Dunning-Lawrence. Cloth.
- B. E. Grant, M. W. S. E.—  
 33d Annual Report, Department of Public Works, Chicago. 1908.
- Mining and Scientific Press—  
 Testing for Metallurgical Processes, James A. Barr. Cloth.
- California State Board of Health—  
 Monthly Bulletins, 1910. Pam.
- John Wiley & Sons, New York—  
 Track Formulæ and Tables, Shelby S. Roberts. Cloth.
- Engineering News Book Department—  
 Clarification of Sewage, Schmeitzner. Cloth.
- Mining and Scientific Press—  
 Practical Stamp Milling and Amalgamation. H. W. MacFarren. Cloth.
- Prof. W. F. M. Goss, M. W. S. E.—  
 University of Illinois Bulletins, 27-34; 35-42. 2, Cloth.
- William Kent—  
 Kent's Mechanical Engineers' Pocket-Book, 1910. Leather.

## EXCHANGES.

- Canada Department of Mines—  
 Recent Advances in the Construction of Electric Furnaces for Iron, etc.  
 Report of Analyses of Ores, Non-Metallic Minerals, Fuels, etc.  
 Geology and Ore Deposits of Hedley Mining District. Pams.
- Tennessee State Geological Survey—  
 Bulletin 2G. Zinc Mining in Tennessee. Pam.
- New Jersey State Board of Health—  
 33d Annual Report, 1909. Cloth.

December, 1910

- Engineers' Society of Western Pennsylvania—  
List of Members, Sept., 1910. Pam.
- Institution of Electrical Engineers, London—  
Journal, Sept., 1910. Pam.  
List of Officers and Members, 1910. Pam.
- Engineering Association of the South—  
Proceedings, July, Aug., Sept., 1910. Pam.
- University of Texas—  
Bulletins Nos. 65, 79, 82, 98, 119, 120, 60, 59, 62, 93,  
102. Pams.
- American Society for Testing Materials—  
Year Book 1910. Cloth.
- Canadian Society of Civil Engineers—  
Transactions, Jan.-June, 1910. Pam.
- Western Australian Institution of Engineers—  
Rules and By-Laws, 1909. Pam.
- Association of Ontario Land Surveyors—  
Annual Report of Proceedings, 1910. Pam.
- New York State Engineer and Surveyor—  
Annual Reports, 1908, 1909. 2, Cloth.
- University of Illinois—  
Bulletin No. 42, The Effect of Keyways on the  
Strength of Shafts. Pam.
- Allen Winch, Chicago—  
The Western Blue Book and Buyers Guide, 1910.  
Cloth.
- John Crerar Library—  
Handbook, 1910. Pam.
- Institution of Civil Engineers, London—  
Minutes of Proceedings, Sept., 1910. Pam.
- National Fire Protection Association—  
Gypsum as a Fireproof Material. Pam.
- Paint Manufacturers' Association—  
Bulletin No. 30, The Tennessee White Paint Tests.  
Pam.
- Boston Street Department—  
Report of Boston Street Department, 1909. Cloth.
- Master Car Builders' Association—  
Proceedings 44th Annual Convention, 1910. Cloth.
- American Society of Civil Engineers—  
Transactions, December, 1910. Pam.
- Rudolph Hering, M. W. S. E.—  
Report on an Improved Water Supply for the City of  
Montreal. Pam.
- Charles River Basin Commission, Boston—  
Final Report of the Charles River Basin Commission,  
1910. Pam.
- GOVERNMENT PUBLICATIONS.
- U. S. Geological Survey—  
Bulletins, Nos. 381, 426, 429, 432, 433, 434, 435, 437, 440,  
444. Pams.  
Professional Paper No. 68. The Ore Deposits of New  
Mexico. Paper.
- Bureau of the Census—  
Bulletin No. 108, Mortality Statistics, 1909. Paper.  
Special Reports, Telephones, 1907. Cloth.  
Report of Commissioner of Corporations on Transpor-  
tation by Water in the U. S. 3 parts. Paper.
- Bureau of Mines—  
Bulletins Nos. 1 & 2. Pams.

## MEMBERSHIP.

Changes of address:

Ahbe, F. R., 1026 Vermont Ave., Washington, D. C.  
 Ashmead, P. H., 43 Exchange Place, New York, N. Y.  
 Beisel, M. J., 1114 Emerson St., Denver, Colo.  
 Binkley, George H., 181 La Salle St., Chicago.  
 Clarke, C. W. E., 147 Milk St., Boston, Mass.  
 Clausen, H. P., care of Stromberg-Carlson Co., Rochester, N. Y.  
 Dance, M. H., 2618 Coliseum St, New Orleans, La.  
 Dodge, G. F., Park Row Bldg., New York, N. Y.  
 Durham, Robert P., 10 St. John St., Montreal, Que.  
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 Greene, Wm. B., Aurora, Ill.  
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Additions:

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John M. Davidson, Gary, Ind.....	Active
Edwin Hancock, Jr., La Grange, Ill.....	Active
Orville H. Drought, Chicago.....	Junior
L. V. Fraley, Chicago.....	Active
George C. D. Lenth, Chicago.....	Active
Edward L. Lahey, Chicago.....	Associate
John Ensink, Chicago .....	Active
Paul L. Battey, Chicago.....	Active
Douglas Graham, Chicago, transfer from Junior.....	Active
Ernst J. Berg, Urbana, Ill.....	Active
James L. Coombes, Chicago.....	Active
William Banne, Chicago.....	Junior
Herbert L. St. John, Chicago.....	Active

Deaths:

Charles L. Gould, Active Member, at Milwaukee, September 18, 1910.  
 Octave Chanute, at Chicago, Honorary Member and Past President.  
 November 23, 1910.

December, 1910

# WESTERN SOCIETY OF ENGINEERS

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First Vice-President.....	O. P. CHAMBERLAIN
Second Vice-President.....	A. BEMENT
Third Vice-President.....	W. K. HATT
Treasurer .....	A. REICHMANN

## TRUSTEES

L. E. RITTER.....	Term expires January, 1911
G. M. BRILL.....	Term expires January, 1912
W. W. CURTIS.....	Term expires January, 1913
W. L. ABBOTT, C. F. LOWETH, ANDREWS ALLEN.....	Past Presidents

The above named officers of the Society and three past presidents  
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Secretary and Librarian  
J. H. WARDER

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W. L. ABBOTT .....	2 years
P. B. WOODWORTH .....	3 years

## BRIDGE AND STRUCTURAL SECTION— EXECUTIVE COMMITTEE

T. L. CONDRON .....	Chairman
W. C. ARMSTRONG .....	Vice-Chairman

### Members of Executive Committee

ANDREWS ALLEN	C. R. DART	F. E. DAVIDSON
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## MEETINGS

- Regular Meeting—First Wednesday evening of each month except January, July and August.  
Bridge and Structural Section—Generally the second Wednesday of the month.  
Extra Meeting—Third Wednesday evening of the month except July and August.  
Electrical Section—Generally the fourth Wednesday evening of the month.  
Board of Direction—The Tuesday preceding the first Wednesday of each month.

## NOTICE

From the dues of each member, \$2.00 is set aside as a subscription to the JOURNAL.









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